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Effect of Insect Residues and Other Factors on Removal of Spray Residues From Apples*

HARRY C. MCLEAN and ALBERT L. WEBER, *New Jersey Agricultural Experiment Station, New Brunswick*

It has been observed in many orchards in New Jersey that frequently residue removal from certain apples was more difficult than from others, although the fruit had been similarly sprayed and contained equal amounts of residue. Two important factors were found to be the cause of these variations; first, insect residues; second, difference in the conditions of the foliage on the trees. Another factor influencing removal of spray residues is the sticker and spreader used in the spray mixtures, especially when an oil plus lead arsenate spray schedule is followed.

INSECT RESIDUES.—It was noted that greater difficulty was experienced in the removal of residue from the fruit from orchards or trees heavily infested late in the season with leafhoppers than from orchards or trees not so infested. Where such infestation was severe the stem cavity of the fruit, at time of harvest, was found to contain a heavy, black organic residue, which had resulted from a fungous infection of the honeydew exuded by these insects. A protective cover of fungous material was thus formed over the spray residue deposited within the stem cavity. This coating appeared to be somewhat impervious to the wash solution and, therefore, was thought to be instrumental in preventing the removal of the spray residues. The foregoing conditions were shown to exist in several different commercial orchards investigated.

McLean & Weber (1934) reported that fungous growth on apples resulting from honeydew exuded by aphids in mid-June did not interfere with spray residue removal. In that case the majority of the lead sprays were applied on top of the fungous growth; therefore, the conditions were different from those attending the leafhopper infestations during August as reported in this paper.

In previous experiments conducted at the New Jersey Agricultural Experiment Station it had been demonstrated that, on an average, 33 per cent of the spray residue deposited on apples lodges in the stem end (McLean 1927).

Table 1.—Influence of leafhopper residue on lead residue removal from Rome apples.

TREATMENT	GRAINS OF LEAD PER POUND OF FRUIT*	
	Lot 1†	Lot 2‡
None	0.115**	0.123
Fruit washed at 70 degrees F.	0.057	0.026
Fruit washed at 70 degrees F. and stem cavity removed before being analyzed	0.006	0.007
Fruit washed at 95 degrees F.	0.017	0.011

* Average of four samples.
† Apples containing black residue in stem cavity.
‡ Apples containing grayish residue in stem cavity.
** Federal tolerance for lead is 0.025 grain of lead per pound of fruit.

In order to determine the manner in which the presence of honeydew affects the accumulation and removal of spray residues, a series of control tests was undertaken in 1936. The results given in table 1, which are from a single orchard, are typical of conditions in many other orchards investigated. These tests were conducted with Rome Beauty apples, a variety which has a wide stem cavity that permits the accumulation of a large amount of spray residue. Rome beauty samples which differed in the character of the residue deposit were selected from the same orchard, lot 1 with heavy black residues in the stem cavity and lot 2 with grayish colored residues. Where the

* Journal Series Paper of the New Jersey Agricultural Experiment Station, Department of Spray Residue Investigations.

fruit was so situated on the trees that it did not receive the honeydew deposit washed from the leaves, practically no fungous growth occurred and a grayish colored residue resulted. Analyses of the fruit were made before and after washing. The fruit was sprayed with acid lead arsenate powder.

All washing tests were conducted in a flotation machine containing 1.75 per cent hydrochloric acid to which were added, for 100 gallons of solution, 8 pounds of *Vatsol*, a paste wetting agent manufactured by the American Cyanamid Chemical Company. The fruit was allowed to remain in contact with the solution mixture for 3 minutes, after which it was thoroughly rinsed with water.

As shown in table 1 there were only slight differences in the total spray residue deposited on the two types of samples selected. Samples with the black deposit (heavy fungous growth) contained on the average, 0.115 grain of lead per pound; whereas those with the grayish deposit (little or no fungous growth) showed 0.123 grain of lead per pound. Repeated tests of such samples gave similar values.

The results presented in table 1 are an average of four different tests. It is apparent that a wide variation in residues remained after the washing treatment. Lot 1 with black residue contained 0.057 grain of lead per pound and lot 2 with grayish residue 0.026 grain of lead per pound, representing a lead residue removal of 50 and 80 per cent respectively.

In order to determine the cause of these large differences in residue content of the washed fruit, further wash tests were conducted with apples containing the two types of residue. In these studies the stem cavities of the apples were removed prior to analysis. The results of these analyses were, lot 1, 0.006 and, lot 2, 0.007 grain of lead per pound of fruit. With the stem cavities eliminated, the residues of both samples, after washing, were practically equivalent. If we consider only the cheek and calyx end of the apple, the character of the stem residue is of little importance. The presence of insect honeydew increased the difficulty of lead residue removal from apples only as it affects removal of residues from the stem ends.

It is important to note also that with both types of residue, heating of the washing solution to 90 degrees F. produced satisfactory lead removal.

PHYSIOLOGICAL CONDITION OF TREES.—Recent experiments were conducted for the purpose of determining the relation of particle size of acid lead arsenate to its adhesiveness. The following materials were used:

Lead Arsenate.—A commercial powdered acid lead arsenate containing 28 per cent of particles below 2 microns in diameter.

Micronized Lead Arsenate.—A lead arsenate having 56 per cent of particles below 2 microns in diameter was prepared mechanically by the Micronizer Processing Company, Inc., from the same batch of lead arsenate as described above.

SSS.—A sticker and spreader in powdered form manufactured by the Mechling Brothers Chemical Company.

Orthol-K.—A medium grade of summer oil emulsion manufactured by the California Spray Chemical Company.

Fluxit.—A colloidal protein spreader manufactured by the Colloidal Products Corporation.

The experiments were conducted upon a block of Rome Beauty apple trees, divided into six plots, each of which received a different spray treatment. Fortunately the plots in this block were laid out in such a manner that each plot contained trees in different levels of physiological condition or growth status, each plot had similar trees, some trees in a very poor condition had but a few thin, light green leaves at harvest time, while those in good condition had many thick, dark green leaves.

When the crop was harvested, samples of fruit were obtained from the different types of trees in each plot and spray removal tests were conducted upon the various samples. As shown in table 2, trees with light foliage bore apples from which spray residue was more difficult to remove than did trees with green, heavy foliage in the same plot. Beginning with the spray application 7 days after the petal fall, all plots received six cover sprays. The plots received the following spray treatments. The amounts given designate the quantity used per 100 gallons of spray mixture: Plot 1, 2 pounds micronized lead arsenate, 1 pound *SSS* sticker, 4 pounds hydrated lime; plot 2, 3 pounds lead arsenate, 1 pound *SSS*

sticker, 4 pounds hydrated lime; plot 3, same treatment as plot 1 for first cover spray followed by 2 pounds micronized lead arsenate, 3 quarts *Orthol-K*, 2 pounds hydrated lime, 0.5 pound *Fluxit;* plot 4, same treatment as plot 2 for first cover spray followed by 3 pounds lead arsenate, 3 quarts *Orthol-K*, 2 pounds hydrated lime, 0.5 pound *Fluxit*.

It is to be noted that the residues were no more difficult to remove from apples the critical period for controlling codling moth. These spreaders, however, did not interfere with spray residue removal from harvested fruit.

Laboratory tests as well as field tests were conducted in New Jersey orchards in an attempt to discover a sticker and spreader which could be used with lead arsenate alone, or with lead arsenate and summer oil, which would give heavy and uniform deposits and good retention of

Table 2.—Influence of foliage condition on spray residue removal. Grains of lead removed per pound of fruit from trees with various foliage conditions.

PLOT NO.	TYPE OF FOLIAGE	NO WASH TREATMENT	ACID* 1.5 MINUTES	ACID† *Vatsol* 1.5 MINUTES	ACID* 2.5 MINUTES	ACID† *Vatsol* 2.5 MINUTES
1	Light	0.070‡	0.025	0.012	0.018	0.009
1	Heavy	0.074	0.018	0.012	0.012	0.006
2	Light	0.078	0.028	0.011	0.018	0.009
2	Heavy	0.081	0.016	0.010	0.010	0.006
3	Light	0.107	0.036	0.024	0.018	0.016
3	Very light	0.100	0.048	0.024	0.026	0.020
3	Extra heavy	0.110	0.025	0.016	0.014	0.012
4	Light	0.122	0.042	0.032	0.036	0.024
4	Very light	0.118	0.050	0.036	0.038	0.028
4	Very heavy	0.124	0.028	0.022	0.024	0.014

* 1.5 per cent acid was used in all Cases.
† 6 pounds dry *Vatsol* per 100 gallons of acid wash solution was used.
‡ Figures indicate grains of lead per pound of fruit.

from oil-sprayed, heavy foliage trees (plots 3 and 4) than they were from fruit grown on non-oil-sprayed light foliage trees in plots 1 and 2.

We believe from physical examination of the fruit that partial defoliation, or poor physiological condition of the tree, causes excessive wax formation and it is this excessive wax that causes the trouble in the spray residue removal.

STICKERS AND SPREADERS.—It has been demonstrated in the past that, when skim milk or other proprietary compounds containing casein are used as spreaders or adhesives in lead arsenate–summer oil spray mixtures applied to apples, the lead and arsenical residues are very difficult to remove from the fruit at the time of harvest (McLean & Weber, 1934). On account of this difficulty, non-casein spreaders were developed for use with lead arsenate in oil spray mixtures. A majority of the newly developed mixtures were found to be good spreaders but did not allow the build-up of a very heavy deposit of lead arsenate on the fruit during lead arsenate upon the fruit during the growing season, but would not cause any great degree of difficulty in removal of spray residue from the fruit at harvest.

Of the many spreaders and stickers tested, a proprietary compound called *Orthex*, manufactured by the California Spray Chemical Company was the one coming nearest to the ideal for the conditions stated above.

In table 3 are given results of washing tests on apples sprayed with *Orthex*–lime–lead arsenate, *Orthex*–oil–lead arsenate as compared with the wash tests upon apples sprayed with the two standard spray schedules recommended in New Jersey; namely, the oil–lead arsenate schedule and the lime–lead arsenate schedule. We have also included tests conducted on apples which had been sprayed throughout the season with a skim milk–oil–lead arsenate spray mixture. In each instance the same number of codling moth cover spray applications was made.

SUMMARY.—Residue removal was found to be more difficult from certain apples

Table 3.—Influence of stickers and spreaders on spray residue removal from apples. Grains of lead removed per pound of fruit from trees sprayed with various stickers.

Sticker Used and Rate Per 100 Gallons of Spray Mixture	No Washing Treatment	Washed in 1.5% HCl for 2½ Minutes	Washed in 1.5% HCl plus 1% *Vatsol* for 2½ Minutes
3 quarts *Orthol-K*, ½ pound *Fluxit*	0.133*	0.019	0.004
¼ pound dry milk	0.161	0.012	—
3 quarts *Orthol-K*, ¼ pound dry milk	0.213	0.111	0.058
1 pint *Orthex*	0.140	0.011	—
2½ quarts *Orthol-K*, 1 pint *Orthex*	0.160	0.021	0.007

* Figures indicate grains of lead per pound of fruit.

than from others in many New Jersey orchards even though they had been similarly sprayed and though they contained an equal amount of spray residue. Two important factors were found to be the cause of these variations: first, insect residues; second, differences in the conditions of the foliage on the trees.

Investigations carried on in a number of New Jersey orchards showed that fungous growth occurring on the honeydew secreted by insects, especially leafhoppers, caused difficulty in removal of lead residues from apples.

The condition of the foliage on apple trees has an important influence on spray residue removal. We found that, for a given spray treatment, the apples from trees with heavy, luxuriant foliage are much easier to wash than those from trees with very light foliage.

The spreader and sticker employed with lead arsenate, especially in summer oil spray mixtures, have an important influence on the spray residue removal from the picked fruit.

Of several materials compared as to their relative effects on deposits and retention of lead arsenate, as well as their influence on removal of residues, *Orthex* had the desirable qualities of producing a heavy coating and of being removed without difficulty in washing.—1-6-39.

Literature Cited

McLean, H. C. 1927. Some results of spray residue on apples in 1927. Proc. Ann. Meet. N. J. State Hort. Soc. 213–25. Dec.

McLean, H. C., and A. L. Weber. 1934. Influence of spray schedule and other factors on spray residue removal. Jour. Econ. Ent. 27(1):168–79.

The Toxicity of Derris to Larvae of the Citrus Whitefly

L. L. English, *Alabama Agricultural Experiment Station, Auburn*

The object of the author of this paper is to present a study of the toxicity of derris to the larvae of the citrus whitefly, *Dialeurodes citri* Ashm. The insects were abundantly available and an experimental technique was worked out which was both accurate and labor saving. Since the larvae of *D. citri* are sessile, of rather uniform viability and easily counted, they make an almost ideal subject for testing contact sprays.

Method.—All the experiments were conducted out of doors, and most of the tests were made in the winter when only the larval stage was present. Leaves on infested trees were selected for uniformity of infestation and larval viability. The sprays were prepared in the laboratory in 100 cubic centimeter quantities and taken to the field in Erlenmeyer flasks. Three leaves were usually selected for each spray. A piece of cardboard, 8½×11 inches, was slit about halfway to the center so that it could be slipped over the leaf petioles to serve as a shield for nearby leaves. The leaf to be sprayed was held in place against the cardboard with a pair of forceps while the spray was applied with an ordinary nasal atomizer. The spraying was continued until run-off be-

gan, and in nearly all cases film coverage was obtained. After 2 to 4 weeks, depending on the weather, the leaves were clipped from the trees, carried to the laboratory and counts made with the aid of a binocular microscope. Usually there were enough larvae to make a minimum count of 300 from each leaf; hence the counts approximated 900 larvae for each spray material. The natural mortality of untreated checks varied from 15 to 18 per cent. All results were calculated to per cent kill or "check basis" by the formula, per cent kill $= (b-a)\ 100/100-a$, where a is the per cent dead on the check and b is the per cent dead on the treated leaves (Tattersfield & Morris 1924). A derris powder containing 5 per cent rotenone was selected for the tests.

EXPERIMENTS WITH EMULSIONS AND DERRIS.—In a preliminary experiment an emulsion (*SM-154*) made from an 83 viscosity white oil and powdered skim milk appeared to be more effective with derris to whitefly larvae than sodium oleyl sulfate and diglycol laurate (fig. 1).

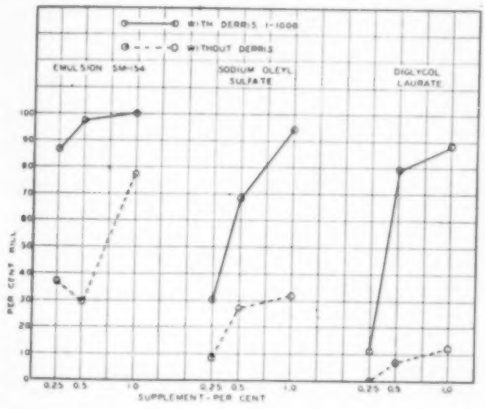

FIG. 1.—A comparison of emulsion *SM-154*, sodium oleyl sulfate, and diglycol laurate as supplements for derris. Powdered derris used as 1 part to 1,000 of liquid spray.

Emulsions were then prepared from the 83 viscosity oil, using powdered skim milk, diglycol laurate, *Grand Pa's Soap* and triethanolamine oleate as emulsifying agents. Diglycol laurate and triethanolamine oleate were dispersed in the oil, 1 part to 9, to make "soluble oils" before dilution with water. Powdered skim milk and *Grand Pa's Soap* were dispersed in water and the oil added to make "stock" emulsions. Two and one-half grams of powdered skim milk in 50 cubic centimeters of water and 10 cubic centimeters of *Grand Pa's Soap* with 40 cubic centimeters of water were used to emulsify 100 cubic centimeters of the oil. All were used at equivalent oil concentrations.

Fig. 2 shows that the highest kill was obtained with the skim milk emulsion. The next most effective emulsion was

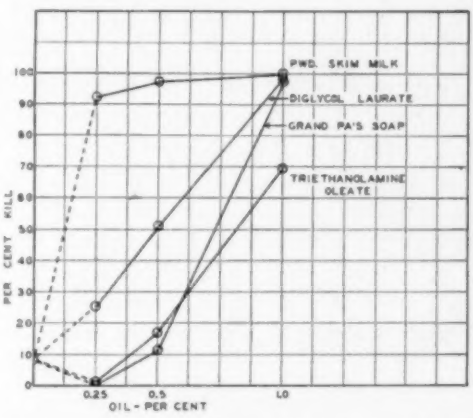

FIG. 2.—A comparison of emulsifying agents for an 83 (Saybolt) viscosity white oil when used with powdered derris, 1–1,000.

that prepared with diglycol laurate, while the *Grand Pa's Soap* and triethanolamine oleate emulsions were the least effective. The effectiveness of these emulsions as derris supplements was, roughly, inversely in order of their stability or degree of dispersion. The triethanolamine oleate emulsion was a very stable, highly dispersed system.

A further interest in the relative efficiency of supplements led to another comparison of emulsions made with diglycol laurate and powdered skim milk. In this experiment the emulsions were used at four concentrations, both with derris, 1–1,000, and without derris. The results given in fig. 3 substantiate results of the previous experiment in that the skim milk emulsion was the most effective. It should be pointed out, however, that a considerable proportion of the kill obtained with this emulsion was due to the action of the oil itself. This may be brought out by an examination of the ratio of the kill with emulsion-plus-derris to the kill with emulsion. From fig. 4, it will be seen that at an oil concentration of 0.062 per cent this ratio was 22.8 for

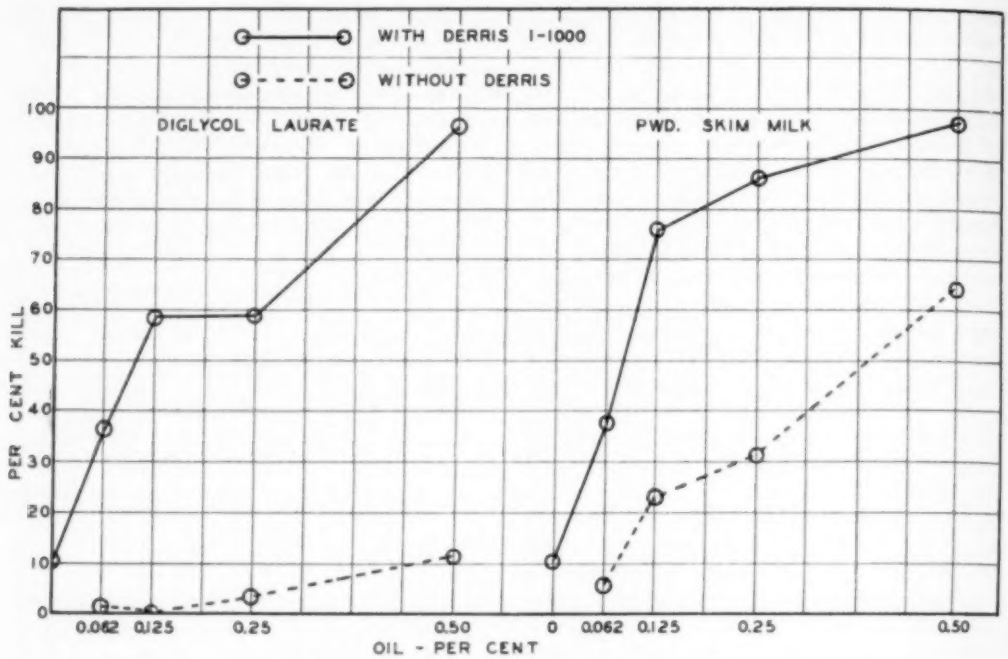

FIG. 3.—A further comparison of diglycol laurate and powdered skim milk for the preparation of emulsions to supplement derris. Powdered derris used at 1 part to 1,000 of emulsion.

the diglycol laurate emulsion and 6.3 for the skim milk emulsion. At 0.25 per cent the ratios were 17.3 and 2.7, and at 0.5 per cent the ratios were 8.6 and 1.5, respectively.

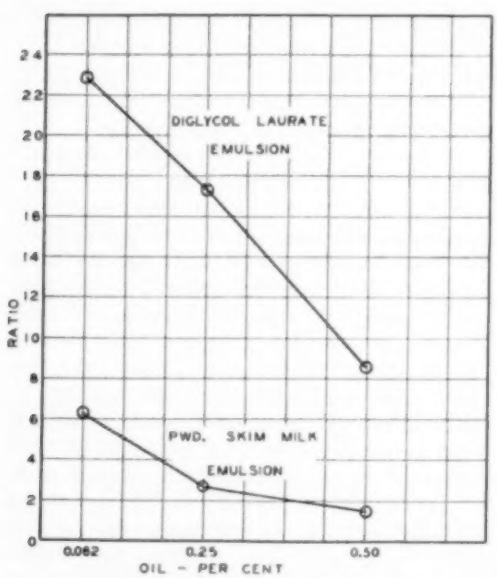

FIG. 4.—Radio of kill of whitefly larvae obtained with emulsion-plus-derris to that obtained with the emulsion.

Because of the apparent efficiency of emulsions made with diglycol laurate, this agent was chosen for comparison with diglycol oleate and with sodium oleyl sulfate. All the agents were dispersed in the oil in the proportion of 1 to 9 before being diluted with water to make concentrations of 0.25, 0.50 and 1.0 per cent. The data in fig. 5 show that digylcol laurate

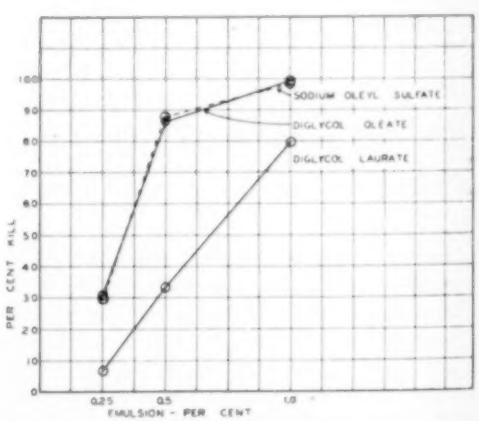

FIG. 5.—The efficiency of sodium oleyl sulfate, diglycol oleate and diglycol laurate for the preparation of emulsions, to supplement derris. Powdered derris used at the rate of 2 parts to 1,000 of liquid spray.

was the least effective of the three agents. There was no appreciable difference in the effectiveness of emulsions prepared from diglycol oleate and from sodium oleyl sulfate.

EFFECT OF DERRIS ON DILUTE OIL EMULSIONS.—Emulsions are highly complex systems and persons who have worked with them keenly appreciate the fact that their insecticidal properties can be altered by apparently trivial factors. Hence the question arose as to whether derris used with emulsions was really a toxic supplement or whether it so altered the physical properties of the emulsion as to increase the effectiveness of the oil. To answer this question definitely a sample of derris was extracted in a Soxhlet apparatus with 95 per cent ethyl alcohol for 7 hours and then with acetone for the same length of time. This was expected to remove most of the toxic constituents (Ginsburg, Schmitt & Granett 1934). This extracted residue was sieved to remove lumps and its toxicity compared with unextracted derris from the same lot. Three supplements were used: diglycol laurate, an emulsion made with diglycol laurate and an 83 viscosity white oil, and one made with powdered skim milk and the same white oil. From the data in fig. 6, it is evident that the constituents removed by alcohol and acetone were responsible for the toxicity of derris. Further, at 4 parts per 1,000, the extracted derris actually reduced the effectiveness of the two dilute emulsions, indicating that some of the oil was removed from the effective phase by absorption. Thus it may be concluded that derris added to emulsions does not improve the insecticidal properties purely on physical grounds; in fact, it may be antagonistic to their action.

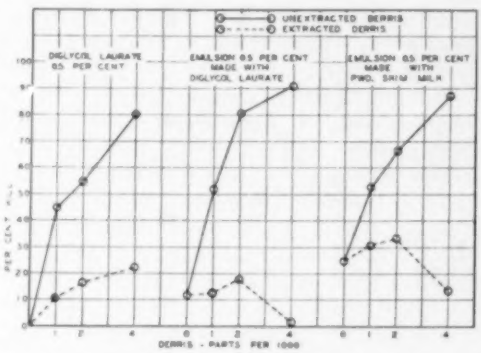
UNEXTRACTED DERRIS
EXTRACTED DERRIS
DIGLYCOL LAURATE 65 PER CENT
EMULSION 65 PER CENT MADE WITH DIGLYCOL LAURATE
EMULSION 65 PER CENT MADE WITH PWD. SKIM MILK
PER CENT KILL
DERRIS - PARTS PER 1000

FIG. 6.—The effectiveness, against whitefly larvae, of extracted and unextracted derris with three supplements.

SUMMARY.—Dilute oil emulsions were effective supplements for derris against larvae of the citrus whitefly. The efficiency of the emulsions for this purpose varied greatly with the emulsifying agent used. With an 83 viscosity oil, powdered skim milk produced a more effective emulsion than diglycol laurate, but a greater proportion of the kill obtained with the skim milk emulsion was due to the oil itself, rather than to the derris. An experiment with extracted and unextracted derris showed that derris was a true toxic agent to citrus whitefly larvae. The data also indicated that derris may be physically antagonistic to the insecticidal action of dilute emulsions.—1-6-39.

LITERATURE CITED

Ginsburg, Jos. M., John B. Schmitt, and Philip Granett. 1934. Derris insecticides I. Toxicity of various extracts of derris root to sucking and chewing insects. N. J. Ag. Exp. Sta. Bul. **576.**

Tattersfield, F., and H. M. Morris. 1924. An apparatus for testing the toxic values of contact insecticides under controlled conditions Bul. Ent. Res. **14**(3):232.

The Cherry Casebearer, *Coleophora pruniella* Clem., in Oregon

TSAI YU HSIAO and DON C. MOTE, *Oregon State College*

The casebearers as a whole are often regarded as minor pests, for usually they occur in small numbers on wild plants. However, when they extend their hosts to cultivated plants and occasionally become abundant as in the case of the cigar casebearer, *Coleophora fletcherella* Fern., the pistol casebearer, *Coleophora malivorella* Riley, and the cherry casebearer, *Coleophora pruniella* Clem., they cause considerable damage to the orchards. Among these three, the pistol casebearer has not

been recorded in Oregon. The cigar casebearer is relatively common on hawthorn and neglected apple and pear trees. Empty cases have been collected on *Cotoneaster*, which has not been previously known as a host plant. The cherry casebearer* was discovered in Oregon in the spring of 1937.

According to the records of the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, this insect has not been previously known from so far west as Oregon. Rather heavy damage was done in apple orchards near Salem. Most of the specimens used in our life history studies were collected on apple and cherry trees around Corvallis, and a few came from the trees around Salem, Portland and Monroe.

SEASONAL HISTORY AND HABITS.—The cherry casebearer has only one generation per year in Oregon and winters over in the half grown larval stage. More than half of its lifetime is spent in hibernation on the twigs of the tree.

In the early spring, as soon as the buds begin to open, caterpillars free their cases from the twigs and move to the young foliage. In 1937 the cases began to loosen from the branches about April 1 near Corvallis, and on April 10 most of them were carried to the expanding leaves. The migration continued until the middle part of April. In feeding, the caterpillar firmly glues its case at the front end to the lower surface of the leaves and bores a small round hole in the epidermis of the leaf large enough to allow it to penetrate into the inner part of the leaf. It stretches out from its protective case and feeds on the inner part of the leaf tissue between the two layers of epidermis without injuring them.

The excavations that it makes on the foliage are conspicuous and easily recognized. They are skeletonized, dead and brown areas of irregular shape and size, with a clean-cut, small, round hole through one epidermis near the center. One larva can make as many as 5 to 10 such excavations before it reaches the pupal stage. The caterpillars feed mainly on leaves, but sometimes they are also observed to attack the flowers, calyx and even the young fruit.

While the larva continues feeding and growing it adds additional parts from time to time to its case in order to make it larger to fit its growing body. The additions are made by cutting the mined part on the edge of the leaf, leaving on the leaf a triangular notch. Usually two such additions are made to the case in the spring and one is often made in the late fall before the casebearer goes in to hibernation, and thus in a fully constructed case one can detect four distinct sections.

Toward the first part of June the majority of the larvae reach maturity and fasten their cases on the upper surface of the leaves or to a small branch and begin to pupate. After fastening its case and before transforming into a pupa, the caterpillar turns around in its case so that the head end of the pupa is toward the posterior and upper end of the case. The opening at this end is closed by two compressed lobes which are readily pushed apart by the emerging adult. The pupa in the season of 1937 was observed as early as May 5 in the laboratory, and as late as July 16 a few pupae were still found in the field. The pupal stage lasts about 3 weeks.

In the rearing cages some moths emerged as early as May 27 and the maximum emergence of adults took place between June 10 and July 20.

Two or 3 days after their appearance, the moths begin to lay their tiny yellow eggs singly in no definite order with the under side broadly glued to the lower surface of the leaves.

The laying ability of the female varies widely. From a few to more than one hundred eggs were laid by the individuals in the cage. The duration of oviposition is observed to occupy from 1 to 3 days per individual.

The embryonic development of the eggs lasts for about 2 weeks. At the approach of hatching the young larva within the egg is plainly visible under a hand lens. It curls in the egg shell with the head toward the margin next to the leaf. Upon hatching, the tiny brown larva emerges through the under side of the egg and enters the leaf directly between the two epidermis layers without being openly exposed. It mines where it gets in and lives as a miner for a period of about 2 or more weeks, using the egg shell as a

* Specimens were determined by Carl Heinrich, U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.

temporary protective case. Then it constructs a small irregular shaped case out of the two leaf layers by cutting through them along the margin of the mine, leaving a few strands uncut at the ends of the case to hold the skins in position while they are being neatly joined together with its secretion. When the work is complete it holds the leaf and manages to break off the case and carry it to some uninjured part of the leaf, and thereafter it mines the leaf from the case. Most of the tiny caterpillars complete their cases during the latter part of August and the beginning of September.

After the early hatched young larvae feed for about 2 or more weeks, they find that their first or primary case is too small for them. They then come to the edge of the leaf and make one addition to their primary case in the manner just stated. By September 9, we found some small cases with one additional part. However, most late hatched larvae winter in their simple primary cases.

Before the leaves of the trees fall, the sensitive little caterpillars, already half-grown, begin their march from their feeding quarters to the bark and attach themselves in the vicinity of the buds for overwintering. In the season of 1937, some caterpillars were observed hibernating on September 26. The majority of the wintering migration, however, takes place in the early part of October.

NATURAL ENEMIES.—The cherry casebearer is beset with many natural enemies, among which the parasites are the most important.

In our cage, two species of hymenopterous parasites, *Eurydinota lividi-corpus* Gir.* and *Microbracon pygmaeus* (Prov.),† were reared. Each emerged the latter part of June. They fed on the larvae and when mature bored a hole in the side of the case of their host and emerged as adults. In our collections several empty cases with a hole on the side were found.—1-6-39.

* Determined by A. B. Gahan, U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.
† Determined by C. F. W. Muesebeck, U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.

The Effects of Neutral Copper Fungicides on Tank-Mix Nicotine-Bentonite in Control of the Codling Moth

L. F. STEINER and J. E. FAHEY, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Because of the promise shown by fixed nicotine sprays against the codling moth, their incompatibility with alkaline fungicides and the need for summer fungicides in Midwestern apple orchards, tests involving five different "neutral" copper compounds were made in southern Indiana during 1938. These materials were used with the tank-mix combination of nicotine sulfate, Wyoming bentonite, soybean oil and sodium lauryl sulfate, which has given outstanding results in southern Indiana (Steiner & Sazama 1938). The experiments were carried on through periods that included several cover sprays for each combination.

METHODS.—The laboratory-field method as described by Steiner & Sazama (1938) was followed in these experiments. The sprays were applied at 450 pounds pressure through a short gun from a 10-foot tower, and through a three-nozzle broom from the ground. On the average, 35 gallons per tree were applied at each spraying to the 23-year old Grimes trees used for these experiments. For each chemical determination, lots of 50 apples were taken as "stratified" samples from each plot, and similar lots of 80 apples for each determination of efficiency. The latter samples were set up in replications and exposed to the attack of 640 newly hatched larvae, eight per apple, under controlled laboratory conditions of 82 degrees F. and 60 per cent relative humidity. Efficiency was calculated by comparisons of the kill obtained on the treated fruit with that on unsprayed fruit. Stings were recorded but did not enter into the percentage efficiency rating. Worms successfully entering the unsprayed samples ranged from 80 to 90 per cent for 13 separate experiments and averaged 83.6 per cent. A total of 40,000 newly hatched larvae were used for the experiments reported herein.

Observations over a period of 5 years have indicated that larvicidal efficiencies in excess of 85 per cent, as determined by this method, are equivalent to almost perfect control under normal field conditions. Early in the season, especially, control under field conditions has been found much higher than that indicated by the laboratory results.

The reliability of the sampling technique and experimental design has been thoroughly tested by statistical analysis. The analysis of variance (Snedecor 1937) was applied to each experiment.

In the determination of nicotine residues the method described by L. N. Markwood (1939) was employed. Statistical study of the analyses of individual fruits by this method indicates that with 50-fruit samples selected as described above, differences of 20 per cent of the common mean would usually be significant at odds of 99 to 1, where the means approximated 3.0 micrograms per square centimeter. In a few instances copper analyses were made, employing the Association of Official Agricultural Chemists' (1935) method for determination of copper in foods.

MATERIALS TESTED.—The tank-mix formula used consisted of five-sixteenths ounce sodium lauryl sulfate,* 1 pint nicotine sulfate (40 per cent nicotine), 5 pounds bentonite (Wyoming bentonite in pellet form) and 1 quart crude domestic raw soybean oil per 100 gallons. For the final application in each series of tests, the nicotine sulfate was reduced to two-thirds pint and the bentonite to 3.3 pounds per 100 gallons, the other ingredients remaining unchanged.

The copper fungicides utilized are listed in table 1, with their analyses and pH values.

In the case of fungicide A, the copper content is equivalent to 103.3 per cent, and the phosphate content to 105.2 per cent of the compound $Cu_3(PO_4)_2 \cdot 3H_2O$ which it is assumed to contain. Similarly, the copper and sulfate contents of fungicide D are equivalent to 90.4 and 117.3 per cent, respectively, of the postulated compound $CuSO_4 \cdot 3Cu(OH)_2$. In the case of fungicide E, the copper corresponds to 92.8 and the chlorine to 84.6 per cent of the suggested principal component $CuCl_2 \cdot 2CuO \cdot 4H_2O$. The pH values of spray mixtures of the fungicides with nicotine-bentonite in spray water ranged from 7.2 to 7.7, indicating that the spray water or nicotine-bentonite counteracted the alkalinity of fungicides B and E, which, however, was not enough in either case to decompose the nicotine-bentonite compound.

Table 1.—Analyses and pH values of copper fungicides used with tank-mix nicotine-bentonite.

Copper Compound	Composition (in Per Cent)				Formula of Most Probable Principal Component	pH of Suspension	
	Metals		Acid Radicals			In Distilled Water	In Spray Mixture
A	Cu	45.3	PO_4	46.0	$Cu_3(PO_4)_2 \cdot 3H_2O$	7.1	7.2
B	Cu Zn	26.7 4.1	SiO_2 SO_4	21.3 10.2		8.0	7.5
C	Cu	30.8	SiO_2 Al_2O_3	35.9 12.0		7.1	7.4
D	Cu	50.8	SO_4	24.9	$CuSO_4 \cdot 3Cu(OH)_2$	6.9	7.3
E	Cu	48.4	Cl	16.4	$CuCl_2 \cdot 2CuO \cdot 4H_2O$	8.4	7.7
Water or mixture without copper fungicide						7.0	7.4

TESTS WITH COPPERS A AND B.—The tests involving copper fungicides A and B were carried on during May and June, 1938. Sprays were applied to all plots on May 6, 16 and 26 and June 8 and 21. The copper fungicides were used in all applications except the first. Copper A was used at the strength of 2 pounds per 100 gallons until the last application, in which the strength was reduced to 1 pound. Copper B was used at 2½ pounds per 100 gal-

* A packaged commercial form containing almost 50 per cent sodium sulfate as a diluent was used at the rate of one-half ounce per 100 gallons.

lons on May 16, 3 pounds on May 26 and June 8, and 1 pound on June 21. The data resulting from this series of tests are given in table 2, and the information on nicotine deposits and larvicidal efficiency is shown graphically in fig. 1.

With each copper preparation the addition of the copper fungicide appeared to bring about more of a decrease in nicotine deposit than occurred with the nicotine-bentonite alone, as well as a greater loss in insecticidal efficiency. The reductions in the quantities of copper materials in the June 21 spray did not prevent serious reductions in efficiency. The trends were on the whole consistent, and most of the individual differences were statistically significant.

In addition to the efficiency losses associated with reductions in nicotine deposits, there were also some cases of apparently lowered toxicity with equivalent deposits, or equivalent toxicity with widely different deposits, associated with the addition of the copper material. This appears especially in the comparison of nicotine-bentonite alone, with the same material plus copper B on May 19 and May 25. The exact reason for the loss in toxicity has not been determined, but the physical nature of the fixed nicotine deposit is known to be important, a smooth film type of coverage generally being much more toxic. The addition of copper compounds resulted in a more spotted or blotchy coverage. There were a number of cases in which the nicotine-bentonite with copper deposited greater quantities of nicotine than the nicotine-bentonite alone, but this was more than offset by the greater losses between applications.

Both of these copper-nicotine treatments were discontinued early in July because of severe russeting and cracking of the fruit and injury to the foliage, which finally resulted in the dropping of at least 35 per cent of the foliage.

Table 2.—Larvicidal efficiency and nicotine deposits from nicotine-bentonite alone and with coppers A and B, and rainfall between sample dates, Vincennes, Ind., 1938.

Date of Sample	Inches of Rainfall Since Preceding Sample Date	No Copper Added		With Copper A		With Copper B		Required Difference for 99:1 Odds (In Per Cent Efficiency)
		Per Cent Efficiency	Nicotine Deposit in Mmg. Per 1 Sq. Cm.	Per Cent Efficiency	Nicotine Deposit in Mmg. Per 1 Sq. Cm.	Per Cent Efficiency	Nicotine Deposit in Mmg. Per 1 Sq. Cm.	
May 16	—	45.4	2.9	45.4	2.9	45.4	2.9	—
May 19	0.48	68.8	4.5	63.8	4.9	58.0	6.6	7.5
May 25	3.80	49.7	3.2	36.7	2.7	35.7	3.2	8.1
May 27	0.00	76.4	8.0	74.2	7.9	64.0	7.5	9.5
June 6	0.97	73.3	3.0	58.2	1.8	45.3	1.2	9.8
June 9	0.35	89.3	7.2	86.1	6.6	83.4	7.1	8.0
June 20	1.88	85.3	2.7	58.8	2.4	60.2	1.8	9.1
June 22	0.00	96.9	4.4	91.0	4.3	90.1	3.5	5.1
July 6	7.29	84.8	2.8	56.7	2.3	40.0	1.8	8.0
Average at start of weathering periods		82.8	6.0	78.8	5.9	73.9	6.2	—
Average at close of weathering periods		73.3	2.9	52.6	2.3	45.3	2.0	—
Average loss during weathering periods		9.5	3.1	26.2	3.6	28.6	4.2	—

TESTS WITH COPPERS C, D AND E.—When it became evident that both coppers A and B at the dosage used were unsafe to the tree and destructive to the high efficiency of the fixed nicotine, tests with three other copper compounds were inaugurated on four trees. Two of these trees had received one application of the tank-mix nicotine-bentonite treatment about the middle of June, and the other two had been unsprayed. Sprays were applied to all the trees on July 19 and August 1. The copper fungicides were used throughout at a strength of 1½ pounds per 100 gallons. The data from this series of tests are given in table 3.

In the evaluation of these data, allowance should be made for the presence at the start of the experiments of a small quantity of nicotine on the trees sprayed

with nicotine-bentonite alone and with copper C. This latter mixture showed no significantly greater loss in deposit or in efficiency, as compared with nicotine-bentonite alone, for the period July 19 to August 1. During the 18-day interval after the second spray, however, there was a significantly greater loss in both efficiency and deposit where copper C had been added. The mixtures that included

nificantly less on August 18 than before the August 1 spray.

No injury to fruit occurred on these trees, but the characteristic purplish spotting and subsequent yellowing of many leaves occurred within a week after application of the July 19 spray on the copper C (zeolite) and copper E (oxychloride) trees. No injury was present at that time on the other two trees, but within a week

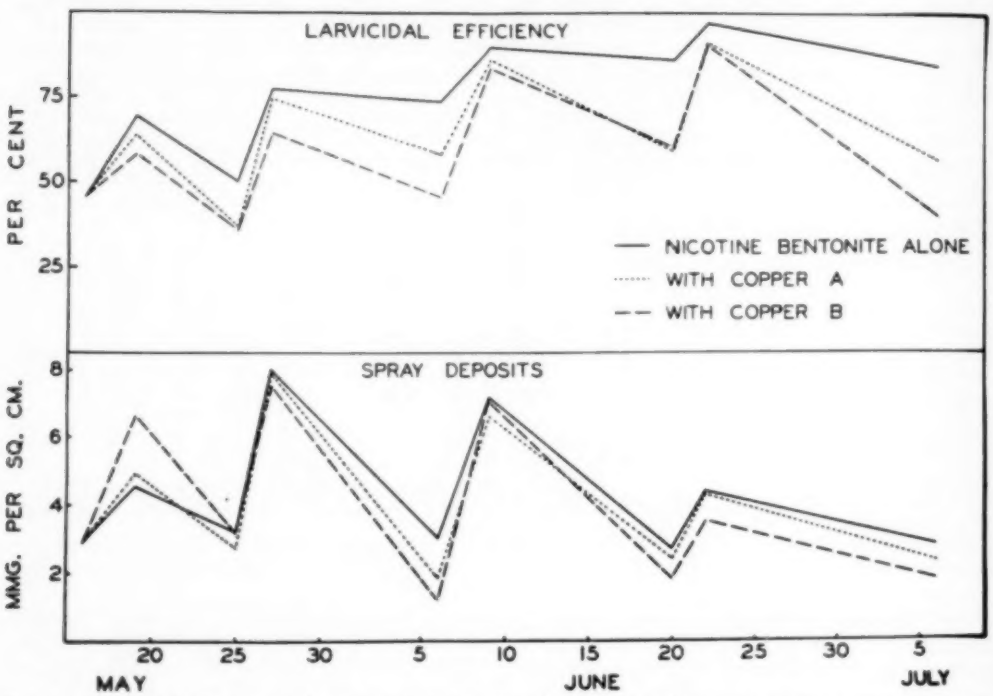

FIG. 1.—Larvicidal efficiency and nicotine deposits maintained with tank-mix nicotine–bentonite–soybean oil alone and with neutral copper fungicides A and B, Vincennes, Ind. 1938.

coppers D and E, although equal to the other two treatments in efficiency shortly after the spray application, declined more rapidly. The presence of the 0.9 microgram deposit on the trees receiving nicotine-bentonite alone and with copper C, that had successfully survived 7.64 inches of rain between June 13 and July 14, may have been a factor in producing these differences. That the coppers also adversely affected the nicotine deposit is indicated by the decline of both deposit and efficiency on all three copper-sprayed trees between August 1 and 18 to lower levels than they had maintained before the August 1 spray, whereas in the absence of copper the efficiency was not significantly less on August 18 than before the August 1 spray.

No injury to fruit occurred on these trees, but the characteristic purplish spotting and subsequent yellowing of many leaves occurred within a week after application of the July 19 spray on the copper C (zeolite) and copper E (oxychloride) trees. No injury was present at that time on the other two trees, but within a week after the final spray, severe injury also developed from the copper D treatment. The foliage turned yellow on all copper-sprayed trees and a few days later began dropping. The loss of foliage approximated 20 per cent from coppers C, D and E.

Further evidence that copper E (oxychloride) adversely affected the tank-mix nicotine was obtained from larvicidal efficiency and deposit data accumulated during the 1938 season in the orchard of a local grower who used a nicotine program on 180 acres. Copper oxychloride was added at the rate of one-half pound per 100 gallons on June 17, and at the rate of 1¼ pounds on July 6. Prior to its

inclusion in the formula the efficiency of this treatment was equal or superior to that reported in table 2, for the nicotine alone, but by July 6 the efficiency had dropped from above 80 per cent to 55.4 per cent. Severe copper injury with up to 50 per cent defoliation occurred on some trees bearing light crops following the use of this copper compound. Trees bearing heavy crops were noticeably less injured in all parts of the orchard.

Although it is possible that the tank-mix formula tends to leave a greater and more permanent deposit of copper, it should be added that the 1938 season was highly favorable to the production of copper injury. For the first time in 5 years copper injury to foliage resulted from the use of ¾–1¼–100 Bordeaux mixture with lead arsenate in five and seven cover sprays. As a matter of record, on June 2 copper deposits on a lead arsenate–Bordeaux plot and on the nicotine-bentonite plots where coppers A and B had been used were 2.0, 9.0 and 8.2 micrograms copper per square centimeter, respectively. On June 13 they were found to be 1.6, 7.1 and 6.2 micrograms copper per square centimeter for the three treatments, respectively. At the beginning of harvest, on August 24, the lead arsenate–Bordeaux treatment had a copper residue of 1.1 micrograms per square centimeter while the copper A and B plots, unsprayed after June 21, had 1.5 and 1.9 micrograms, respectively. The fixed-nicotine plots to which coppers C, D and E were last applied on August 1 still retained 2.8, 13.4 and 7.5 micrograms of copper per square centimeter, respectively.

No spray injury occurred from the use of the tank-mix nicotine–bentonite–soybean oil combination alone, although an effort was made to determine whether injury could be produced by applying 13 successive sprays to the same trees of the Jonathan, Grimes, Ben Davis and Winesap varieties.

SUMMARY AND CONCLUSIONS.—At the present time copper fungicides are necessary in the Midwest for the control of certain apple diseases. The high efficiency against codling moth larvae and the larger nicotine deposits which may be built up and maintained with applications of tank-mix nicotine–bentonite–soybean oil are adversely affected by the inclusion of any one of several neutral copper fungicides in the formula. Of five tested, each reduced the resistance of the nicotine deposits to the weathering effects of heavy rains and also reduced the effectiveness of tank-mix-nicotine–bentonite in codling moth control. There was also evidence that at least one substantially depressed the toxicity of the nicotine deposit.

All five copper compounds produced very serious foliage injury and two used early in the season caused severe russeting and cracking of Grimes fruit. Foliage injury from copper, however, was also produced in 1938 by applications of ¾–1¼–100 Bordeaux mixture with lead arsenate.—1-6-39.

Table 3.—Larvicidal efficiency and nicotine deposits obtained by use of nicotine-bentonite alone and with coppers C, D and E, Vincennes, Ind., 1938.

Date of Sample	Inches of Rainfall Since Preceding Sample Date	No Copper Added		With Copper C		With Copper D		With Copper E		Required Difference for 99:1 Odds (In Per Cent Efficiency)
		Per Cent Efficiency	Nicotine Deposit in 1 Sq. Cm. Mmg. Per	Per Cent Efficiency	Nicotine Deposit in Mmg. Per 1 Sq. Cm.	Per Cent Efficiency	Nicotine Deposit in Mmg. Per 1 Sq. Cm.	Per Cent Efficiency	Nicotine Deposit in Mmg. Per 1 Sq. Cm.	
July 14	—	48.9	0.9	50.9	0.9	0.0	0.0	0.0	0.0	9.5
July 19	1.16	96.4	6.7	98.5	5.0	95.0	6.2	95.4	5.3	4.7
Aug. 1	1.22	83.9	1.7	81.1	1.5	66.7	1.0	67.4	1.1	5.1
Aug. 1	0.00	97.7	3.6	96.3	3.9	94.7	3.9	94.5	2.6	5.1
Aug. 18	3.90	80.9	1.9	56.9	1.3	52.9	0.7	47.7	0.8	6.7

LITERATURE CITED

Association of Official Agricultural Chemists, 1935. Official and tentative methods of analysis, copper-tentative, p. 398.

Markwood, L. N. The photometric determination of nicotine on apples without distillation. Jour. Assoc. of Official Ag. Chemists. **22**(2):427–36.

Snedecor, George W. 1937. Statistical methods, pp. 171–218. Collegiate Press, Inc. Ames, Iowa.

Steiner, L. F., and R. F. Sazama. 1938. Experiments with tank-mix nicotine–bentonite–soybean oil for codling moth control. JOUR. ECON. ENT. **31**(3):366–74.

Preparation of Calcium Arsenates of Low Solubility

O. A. Nelson, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

During recent investigations into the characteristics of the arsenates of calcium as carried out in the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine (Nelson & Cassil 1937; Goodhue 1937) and elsewhere (Pearce & Norton 1936; Waters & Witman 1937), two very significant observations were made: (1) that the high percentage of soluble As_2O_5 as determined by the Geneva method (Pearce, Norton and Chapman 1935) is most assuredly due to the presence of the relatively soluble dicalcium arsenate, and (2) that equilibrium conditions are difficult to obtain even in the laboratory, and except under special conditions are seldom realized in the preparation of the commercial products.

Calcium arsenate is usually prepared by adding the proper quantity of arsenic acid to a suspension of hydrated lime. At the point of contact between the acid and the lime a localized condition is set up, which favors the formation of crystalline dicalcium arsenate. Since this salt is fairly soluble, it might be expected to go back into solution and recombine with the excess lime to form a basic salt. Probably, however, before the dicalcium salt has had time to dissolve, the crystals become coated with a layer of the highly insoluble basic product. This produces particles having cores of dicalcium arsenate, and the only way by which this compound can come in contact with the limewater is by diffusion of the latter through the shell of basic salt. Such a mechanism not only explains the difficulty in attaining equilibrium conditions, but at the same time suggests a method of preparing calcium arsenates containing little or no dicalcium salt, and in which equilibrium conditions are closely approached.

Two methods of procedure were suggested: (1) to add the arsenic acid to the lime suspension and allow sufficient time for all the dicalcium salt to react with the limewater by means of diffusion, and (2) to add the arsenic acid in such a way as to make local action impossible. The first method was used in the author's phase-rule investigations (Nelson & Haring 1937; Smith 1920), and proved to be very time-consuming and thus unsuitable for the preparation of calcium arsenate on a large scale. For this reason a procedure was devised along the lines of the second method.

Description of Method.—The method consists essentially in atomizing a dilute solution of arsenic acid into a suspension of hydrated lime, as suggested in U.S.P. no. 2, 122,861, with vigorous stirring. The phase diagram obtained by Nelson & Haring (1937) was used as a guide in the selection of conditions for this series of experiments. The temperature was maintained at 60–65 degrees C., throughout the entire series, and the ratios of the reactants were so adjusted as to produce a product less acid than tricalcium arsenate. It is evident that with such a procedure the possibility of producing a mixture of basic and acid arsenates is greatly reduced. However calcium arsenates of almost any desired composition can be prepared by this method by the proper choice of conditions. Thus, perfectly formed crystals of dicalcium arsenate were prepared at 65 degrees C. by adding the proper quantity of arsenic acid to a known weight of calcium hydroxide. A solution of lime containing solid calcium hydroxide in suspension is obviously saturated, and, as has been observed in previous experiments (Nelson & Haring 1937), such a condition favors the formation of the tetracalcium arsenate. By adding dilute arsenic acid in the form of exceedingly small droplets evenly distributed over a large surface of saturated limewater, there is slight opportunity for any localized acidification. The nozzle of the atomizer was directed at the center of the surface of the lime suspension, reducing to a minimum the number of droplets coalescing on the walls of the reaction flask. Since the lime solution remains saturated as long as any calcium hydroxide exists in suspension, the reaction can be considered as taking place in a homogeneous system, favoring the rapid establishment of equilibrium.

Fig. 1 shows the apparatus used in this work.

Experimental Results.—The results obtained in experiments with this method are recorded in table 1. In these runs the

time required for atomizing the acid solution into the lime suspension ranged from 15 to 30 minutes. The stirring was then continued for different periods of time. No arsenic remained in any of the solutions at the completion of the experiments, and no free lime was found in any of the products except D-22 and D-23. This was to be expected if equilibrium conditions had been obtained, because the quantities of lime and acid taken were such that no solid lime could remain in suspension after all the acid had been used up.

The first six samples show high water-soluble As_2O_5 as determined by the Geneva method, and the molar ratios of CaO to As_2O_5 lie between that for tricalcium arsenate (3.00) and 3.54, regardless of the time allowed for the reaction to reach equilibrium. The absence of free lime in the precipitates indicates that the reactions had approached equilibrium. Also, these results indicate that to contain a low percentage of soluble As_2O_5 a calcium arsenate must have CaO and As_2O_5 combined in a molar ratio well above 3.50. Further evidence for this may be seen in the results obtained by Nelson & Cassil (1937) in their analysis of commercial calcium arsenates.

Experiments D-11 to D-15 show the effect of the time of stirring on soluble As_2O_5. Here the molar CaO/As_2O_5 ratios average 3.74; the results indicate that equilibrium conditions can be attained within 30 minutes and that further stirring does not materially alter the percentage of soluble As_2O_5 in the product. The remaining experiments lead to the same conclusion, and in addition show that in those runs in which less As_2O_5 was added the percentage of soluble As_2O_5 was slightly lower. The results of the two groups of experiments, D-11 to D-15 and D-18, D-19, and to a lesser degree of D-21 to D-23, indicate that if equilibrium conditions prevail the percentage of soluble As_2O_5 is lower in solutions in which the concentration of calcium hydroxide in solution is high. Whether this is due to the formation of basic solid solution or is simply a common-ion effect has not been determined. In the calcium arsenates

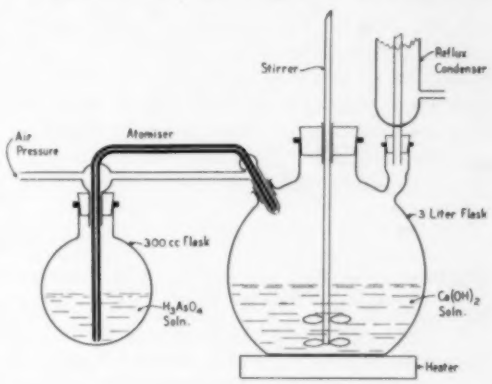

FIG. 1.—Apparatus for preparing calcium arsenates of low solubility.

Table 1.—Experimental data.

Experiment No.	Calcium Hydroxide Used, Grams Per Liter	Arsenic Pentoxide Used, Grams Per 100 cc.	Total Stirring Time, Hours	Analysis of Products			Molar Ratio CaO/As_2O_5
				CaO Per Cent	As_2O_5 Per Cent	Soluble Per Cent	
D-1	2.523	3.380	¼	39.84	53.34	4.86	3.06
D-2	2.523	3.135	1½	41.35	50.76	2.60	3.34
D-3	1.750	2.050	½	40.82	51.12	3.15	3.28
D-4	2.440	2.860	1½	43.10	50.03	2.65	3.54
D-5	2.440	2.780	1¼	41.85	50.16	2.20	3.45
D-6	2.270	2.516	1¼	39.95	47.15	1.70	3.47
D-11	3.500	2.110	½	43.50	47.50	0.70	3.76
D-12	3.500	2.110	1	44.90	49.10	0.75	3.76
D-13	3.500	2.110	2	44.75	48.80	0.25	3.76
D-14	3.500	2.110	3	44.15	48.75	0.60	3.74
D-15	3.500	2.110	¼	43.60	48.50	0.90	3.69
D-18	3.500	1.950	2	44.65	48.95	0.50	3.70
D-19	3.500	1.950	3	44.50	47.60	0.54	3.82
D-20	3.500	2.200	½	44.30	49.10	0.72	3.70
D-21	3.500	2.200	2	44.65	49.40	0.63	3.70
D-22	3.500	1.800	1	47.20	49.40	0.90	3.92
D-23	3.500	1.800	2	43.60	47.50	0.45	3.76

analyzed by Nelson & Cassil (1937) only 4 brands out of 19 investigated showed less than 0.40 per cent of soluble As_2O_5. Two of these were special brands, and all contained 6.00 to 7.5 per cent of free lime.

CONCLUSIONS.—The results obtained in the course of this investigation show that by proper control of conditions calcium arsenates can be prepared that are uniform in composition, basicity and soluble As_2O_5. This method of preparation is simple and easy to carry out, and it should be readily adaptable to production on a commercial scale. It is evident that calcium arsenates of any desired composition, up to a CaO/As_2O_5 ratio of approximately 3.8, can be prepared by simply adjusting the ratio of the reacting substances. Why tetracalcium arsenate does not form under conditions such as prevailed in these experiments, or in the industry, is difficult to explain. This question calls for further investigation.

The mechanism of the reaction in a process such as this, wherein a dilute solution of acid reacts with a saturated solution of calcium hydroxide appears to be the formation of the most basic salt first, which upon further addition of acid goes over into the less basic solid solution. This is in agreeement with previous observations on the formation and stability of tetracalcium arsenate (Nelson & Haring 1937).—9-6-38.

LITERATURE CITED

Goodhue, L. D. 1937. Particle size of commercial calcium arsenates by sedimentation analysis. JOUR. ECON. ENT. **30**(3):466–74. 4 figs. June.

Nelson, O. A., and C. C. Cassil. 1937. An examination of commercial calcium arsenates. JOUR. ECON. ENT. **30**(3):474–8. 1 fig. June.

Nelson, O. A., and M. M. Haring. 1937. Calcium arsenates. An investigation into the three-component system calcium oxide-arsenic oxide-water. Jour. Amer. Chem. Soc. **59**(11):2216–23. 7 figs. Nov.

Smith, C. M. 1920. The arsenates of calcium. I. Equilibrium in the system arsenic pentoxide, calcium oxide, water at 35° (acid section). Jour. Amer. Chem. Soc. **42**(2):259–65. 1 fig. Feb.

Waters, H., and E. Witman. Studies on calcium arsenate. JOUR. ECON. ENT. **30**(1):204–10. 1 fig. Feb.

Pearce, G. W., and L. B. Norton. 1936. A phase rule study of the calcium arsenates. Jour. Amer. Chem. Soc. **58**(7):1104–8. 2 figs. July.

Pearce, G. W., L. B. Norton and P. J. Chapman. 1935. A chemical method for determining the safeness to foliage of commercial calcium arsenates. N. Y. State Ag. Exp. Sta. (Geneva) Tech. Bul. **234**. 15 pp., 1 fig. Oct.

New Method of Using Paradichlorobenzene for Seed Treatment to Control Sweetpotato Weevil

HERBERT L. DOZIER,* *Louisiana Department of Agriculture, Sunset, La.*

For several years the use of paradichlorobenzene has been recommended by government and state agencies as the best known method for treating seed sweetpotatoes to disinfest them of all stages of the root weevil, *Cyclas formicarius* (F). The dosage generally recommended is at the rate of 1 ounce per bushel of potatoes when used in a tight barrel, bin or fumigation room or 2 ounces per bushel for dirt storage banks, over a period of 21 days prior to bedding. When properly applied and under favorable weather conditions, the material gives a kill closely approximating 100 per cent. The main criticism of this method has been the length of time required, and the quite evident retarding of germination through the excessive drying out of the potatoes by the gas which seems to act by a process of slow desiccation.

NEW METHOD OF APPLICATION.—It seems advisable to record a new method, recently worked out, whereby it is possible greatly to shorten the period of fumigation necessary. Instead of allowing the gas to evolve slowly over a period of 21 days, it was found possible to volatilize the same amount of paradichlorobenzene crystals in from 6 to 15 minutes, by use of the patented feature of an electric vacuum cleaner. As this method calls for both the availability of electric current

* The writer wishes to express his appreciation of the kind cooperation of John B. Pitman and D. H. Rutledge of the Air-Way System.

Table 1.—Experiments with paradichlorobenzene immediately volatilized into barrels at room temperature, 1 bushel of sweet potatoes, Sunset, La., 1937.

Treatment	Date	Dosage	Fumigation Period	Number of Dead Weevils			Number of Live Weevils			Per Cent Kill
				Adults	Pupae	Larvae	Adults	Pupae	Larvae	
1	Feb. 11–March 9	6 ounces	27 days	66	26	30	0	0	0	100.00
2	Feb. 20–March 9	3 ounces	16½ days	65	34	9	2	0	4	94.84
3	Feb. 20–March 9	6 ounces	16½ days	3	8	32	0	3	8	79.63
4	Feb. 20–March 9	9 ounces	16½ days	41	7	0	0	0	0	100.00
5	April 6–19	3 ounces	13 days	94	2	11	0	0	0	100.00
6	April 6–19	6 ounces	13 days	61	1	8	0	0	0	100.00
7	April 6–19	6 ounces	13 days	45	0	2	0	0	0	100.00
8	April 6–19	9 ounces	13 days	44	2	7	0	0	0	100.00

and the vacuum cleaner it is automatically ruled out for the majority of farmers. It could, however, be used to good advantage for treatment of quantities of seed potatoes in crates or sacks in large fumigation rooms, centrally located. It would have the advantage of simplicity and cheapness, the reduction of the fumigation period from 21 days to 13 days, less loss from decay due to excessive moisture and handling, and less retarding of germination.

The first experiment was made on February 11, 1937, by volatilizing 6 ounces of the crystals into the original carton container in which a bushel of heavily-infested sweet potatoes had been placed in a sack. On February 14, four potatoes were taken out and dissected, yielding nine adults, three pupae and one larva, all alive. On February 19, four more potatoes were taken out and dissected, yielding four adults and one larva dead, and two pupae and one larva very active. On March 9 the remaining potatoes were taken out and yielded 66 adults, 26 pupae and 29 larvae, all dead, and a single larva alive.

A series of barrel experiments was then initiated on February 20, a bushel of weevil-infested potatoes being used in each. These barrels were covered with loose-fitting lids and sacks and kept stored at ordinary room temperature. Very little gas was lost during the process of volatilization as the gas is about five times as heavy as air. At the end of 16¼ days the potatoes were taken out and found to be in excellent condition, the interior of the barrels very cool and clammy. In each experiment, a small amount of the potatoes was bedded out in the greenhouse. Potatoes bedded on March 10 started to sprout on April 19 and 20, giving an excellent germination. The remainder of the potatoes were dissected immediately and showed a high percentage of kill. Twelve bushels of untreated weevil-infested sweet potatoes from the same source were retained inside the laboratory in a screened cage at the time of this experiment as a check on the natural mortality. These were held until May 26, when an examination showed practically 100 per cent of all stages alive.

A second series of similar barrel experiments, made on April 6, indicated a complete kill when examined on the thirteenth day. Much warmer temperatures prevailed than with the earlier series and may account for the short period and better kill. The results of these experiments are given briefly in table 1. The adults proved to be the most easily killed and the larvae the most difficult.

CONCLUSIONS.—All of these experiments demonstrate that the paradichlorobenzene gas is very slow to penetrate the sweet potato and requires a long period to kill the weevil under the best conditions. It has been proved that 100 per cent kill can be obtained in 13 days and it is possible that this period could be slightly reduced by a few days.—10-5-38.

UNDER the 1939 revision of the Missouri quarantine relating to the European corn borer, which comes in standardized form, green corn is no longer exempt from restriction. Thirteen states are designated as infested, as heretofore, the requirements applying equally, however, to all states with no distinction as to the one-generation or two-generation areas.

Life History Notes on the Cowpea Curculio, *Chalcodermus aeneus* Boh.*

J. M. Langston,† *Mississippi Agricultural Experiment Station, State College*

The observations reported in this paper were made at State College, Mississippi, from 1934 to 1937 in connection with some experimental work on cowpea insects.

Review of Literature.—The cowpea curculio was first described by Boheman in 1837 from Mexico. The first record of its occurrence in the United States was by Horn in 1873, who reported it from Florida and Georgia. Chittenden (1904) mentioned these as well as several other published and unpublished records. About two-thirds of these give cotton as the food plant but, from some notes made by Schwarz in 1887 and from his own work, Chittenden showed this to be a cowpea insect. Champion (1902–1906) records this species from Mexico and Central America and mentions "the two compressed conical tubercles between the eyes in front" as an external character of the female which distinguishes it from the male. Ainslie (1910) gives all the published records up to 1908 and the results of some life history studies made at Clemson College, South Carolina, in 1908 and 1909, including technical descriptions of the egg, larva, pupa and adult with a translation of Boheman's original description. Arant (1938) gives information on the life history and control of this insect in Alabama, and Bissell (1938) has published a paper dealing with the host plants and parasites of this and related species.

Locality and Host Plant Records.—Considering all the previous records and his own observations, Ainslie concluded that the cowpea curculio occurred in all the Southern states as far north as Maryland, Missouri and Oklahoma. Whether or not its present distribution coincides with the present distribution of the cowpea plant is not known to us. In Mississippi it has been reported from 62 of the 82 counties and doubtless occurs in all of them.

The adults of this species often feed on young cotton in the spring, especially where cotton follows cowpeas. They have been found also on butterbeans, cowpeas, string beans, navy beans, mung beans, cocklebur, orange, peach, pear and strawberry. Feeding punctures have been observed in the pods of navy beans in the field. In our cages a number of eggs have been laid in the pods of string beans and three of the insects were reared to the adult stage. All other reared adults have been obtained from eggs laid in cowpeas. Although we have not reared this species from a wild host plant, the presence in this locality of *Strophostyles umbellata* (Muhl.) from which this species has been reared by Bissell in Georgia, and the universal occurrence of this insect in cowpea fields give indications of at least one wild host plant.

Seasonal History.—The cowpea curculio hibernates in the adult stage and emerges in the spring before cowpea pods are available for egg laying. Some of our early collection records are April 3, 1914, May 6, 1912 and May 8, 1931, none of which was taken from cowpeas. Our earliest record of adults collected from cowpea plants is May 11, 1929. Egg laying by adults from hibernation begins as soon as pods are large enough and continues until late September or early October if pods are available. In 20 to 30 days after the first eggs are laid adults of the first generation begin to emerge. In our cages these reared adults began laying eggs in about 10 days and continued until the last of September or the middle of October. These eggs developed into a seond generation of reared adults in 20 to 25 or more days. Only two generations were reared in 1935 and 1937. In 1936 egg laying by hibernating adults was begun about 10 days earlier than in the previous year because cowpeas were planted early and the weather was favorable for the production of pods. As a result a third generation was reared, the adults emerging between September 15 and November 1. Adults from hibernation continued to lay eggs until September 20, 1935, October 10, 1936 and September 20, 1937.

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† Associate in Entomology.

However, eggs laid by these adults after August 20, 1935, September 15, 1936 and September 5, 1937, failed to produce adults in our cages. The last eggs from which adults were reared were laid October 2, 1935, September 25, 1936 and September 18, 1937, by adults reared the same year. Reared adult females emerging before September 20 laid part of their eggs the same year while those that emerged after that date entered hibernation without laying eggs. In 1937 the proportion of the sexes of hibernating adults collected was 2 males to 3 females, reared adults of the first generation 86 males to 61 females and reared adults of the second generation 25 males to 21 females.

Fig. 1 illustrates the seasonal history of this species during its most active period. The horizontal lines that start at the extreme left show the presence of active adults that have passed the previous winter while the lines extending to the extreme right indicate adults going into hibernation. The breaks in the lines to the right indicating the last emergence of adults of the different generations show that all adults of the first reared generation each year had emerged by October 2, while the emergence of the second and third generation adults extended into November.

LIFE HISTORY.—During the summers when our life history studies of this insect were in progress dry weather prevailed and cowpea pods in cages on growing plants often became dry before the curculio larvae completed their growth. As a result most of the larvae failed to emerge and the few that did emerge required what we considered to be much more than the normal number of days to reach the adult stage. One specimen even changed to the adult stage within the pod, which is unusual. By the use of cages in which the moisture could be retained in the pods, as would be the case in seasons of adequate rainfall, adults were reared in a much shorter time and a much larger proportion of the larvae survived.

The eggs of the cowpea curculio are laid in punctures made through the hulls of the pods into the seed. After hatching, the larvae feed within the seed or on the outside of the seed within the pods until full grown, when they emerge through holes cut in the hulls, drop to the ground,

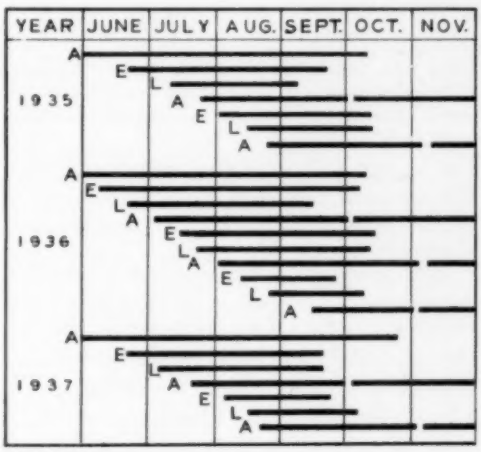

FIG. 1.—The seasonal history of the cowpea curculio as it occurred at State College, Miss., in 1935, 1936 and 1937. *A*, adults present; *E*, eggs laid; *L*, full grown larvae present. The breaks in the lines to the right indicate the approximate dates of emergence of the last adults of each generation.

and enter the soil where the pupal stage is passed and from which the new adults emerge.

The number of adults used in our cages during the period from 1934 to 1937 for each generation, the total number of eggs laid, the deposition dates of the first and last eggs, the total number of adults reared, and the first and last emergence dates are given in table 1.

The egg laying records for 1937, including the total number, lowest, highest and average per adult female, and the dates

Table 1.—Total number of eggs laid and adults reared from 1934 to 1937.

ADULTS OBTAINED	ADULTS	EGGS			ADULTS REARED		
		Number	First	Last	Number	First	Last
From hibernation	76	1,656	6/8	10/5	814	7/7	11/1
First generation	275	2,350	7/14	10/5	328	8/5	10/31
Second generation	82	45	8/13	9/25	10	9/14	11/9

of the first and last eggs laid are given in table 2. These figures may not represent the total number of eggs laid by these females since those from hibernation possibly laid some eggs the previous year. Adults which begin laying eggs the year they are reared probably complete their egg laying the following year, although this was not definitely established as none of the adults with egg records survived the winter.

Table 2.—Average number of eggs per adult female laid in 1937.

Adult Females	Eggs Laid	Eggs Per Female		Dates Laid	
		Range	Average	First	Last
From hibernation 12	602	5–110	54.7	6/22	9/22
First generation 7	170	1–70	24.2	7/23	8/12

The larval stage of the cowpea curculio is divided into four instars, the last of which consists of two parts: that spent in the seed and that spent in the soil before pupation takes place. The lengths of the different instars are difficult to measure because the larvae feed inside the seed and often die when removed for examination. For this reason only a few specimens have been observed through all the instars. By measurement of the head widths and search for head casts of the larvae examined, the number of instars and the approximate length of each was determined. The average lengths of the instars as well as those of the different stages and the number of specimens observed in each case are given in table 3.

Table 3.—Average lengths, in days, of the immature stages of the cowpea curculio.

Stages	First Generation		Second Generation		Third Generation		Average	Number of Specimens
	Range	Average	Range	Average	Range	Average		
Egg	1–7	2.48	1–7	3.10	—	—	2.76	407
Larval Instars								
First	1–7	1.66	1–5	1.69	—	—	1.67	77
Second	1–3	1.53	1–5	1.54	—	—	1.54	55
Third	1–5	2.38	1–8	3.03	—	—	2.73	58
Fourth in seed	1–7	3.5	½–8	1.5	—	—	2.2	31
Fourth in soil	1–13	5.9	3–13	5.89	4–11	6.00	5.89	691
Pupal	3–15	6.88	3–16	6.48	2–15	8.2	6.6	489
Total in seed	4–35	7.95	4–37	7.03	5–9	8.09	7.35	1642
Total in soil	4–30	13.9	6–29	12.76	6–26	14.2	13.35	764
Egg to adult	15–47	20.87	14–42	20.31	17–40	23.8	20.59	658
Adult to egg	—	—	4–16	10.2	—	—	—	—
Egg to egg	—	—	25–38	29.4	—	—	—	—

Summary.—The adults of this species surviving the winter begin to lay eggs as soon as cowpea pods are large enough in the spring and continue until late in September or early October. Two generations were reared in each of the years 1935 and 1937 and three in 1936. Reared adults that emerged after September 20 failed to lay eggs the same year. Most of those emerging before that date begin laying eggs the same year and probably continue the following year.

Eggs of this species are laid in punctures made through the hull into the seed of the cowpea pods. The larvae usually feed inside the seed until full grown, when they emerge and enter the soil for pupation. There are four larval instars, three and a part of the fourth being passed in the seed and the remainder of the fourth in the soil. Under favorable conditions adults will emerge in about 20 to 30 days after egg deposition. With the exception of the last generation, which delays oviposition until the following spring, adults begin laying eggs about 10 days after emergence.—10-12-38.

LITERATURE CITED

Arant, F. S. 1938. Life history and control of the cowpea curculio. Ala. Exp. Sta. Bul. **246.** 34 pp., 14 figs.

Ainslie, G. G. 1910. The cowpea curculio. U. S. Dept. Ag. Bur. Ent. Bul. **85**(8): 129–42. 2 figs.

Bissell, T. L. 1938. The host plants and parasites of the cowpea curculio and other legume infesting weevils. JOUR. ECON. ENT. **31**(4): 534–6. 2 figs. Aug.

Champion, G. C. 1902–1906. Chalcodernus aeneus. Biol. Cent. Am. **4**: 319.

Chittenden, F. H. 1904. The cowpea pod weevil. U. S. Dept. Ag. Bur. Ent. Bul. **44**: 39–43. 3 figs.

Notes on Elm Twig Crotch Injuries Produced by *Scolytus multistriatus* Marsham*

D. O. WOLFENBARGER and W. D. BUCHANAN, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The data and observations presented herewith were made over the 5-year period 1933–1937. The crotches of thousands of twigs from several hundred elm trees were examined for injuries during this time. Examinations were made of trees growing in the states of New York, New Jersey, Connecticut, Pennsylvania, Delaware, Virginia, West Virginia, Ohio, Kentucky and Indiana.

CHARACTER OF INJURY.—The injuries produced by *Scolytus multistriatus* Marsham in the crotches of elm twigs are usually made as short holes or burrows. The beetles generally bore into the center of the crotch or slightly to one side, fig. 1. A small round hole results; this is slightly larger in diameter than the width of the beetle and is perhaps twice as deep as the length of the beetle, as indicated by Collins *et al.* (1936).

The smaller or lateral member of the injured crotch varies from the current season's growth to twigs about three years of age. The main or larger twig member varies usually from about 1 to 5 years in age.

Complete girdling or severance of the twigs may result from severe injuries. The work has been observed to be so severe that all cortical and phloem tissues were undermined or removed from the bases of many twigs. In other cases the twigs were so badly injured that many fell, resulting in partial defoliation of the trees. Some injuries were made by beetles apparently burrowing under the small thin scales of bark on limbs and small branches. These burrowings might be attempts at making galleries for egg deposition. They are usually found where the twig crotch injuries are numerous and severe, a condition which may indicate that an enormous number of beetles has been in the vicinity at one time.

After a beetle bores into the crotch of a twig the tree usually produces wound tissue that gradually fills in and covers the injury, fig. 2. Injuries only a few weeks old may often be completely closed by a callus. Such fresh calluses exhibit a reddish color, whereas calluses a year or more in age usually become as darkened and blackened as the twig bark. The external diagnostic features of callused *Scolytus multistriatus* crotch injuries may often be detected by the characteristic ridged bark formation shown in fig. 3. A crotch with this formation is easily distinguished from an uninjured crotch, fig. 4.

The tissues in and about a fresh crotch wound quickly become darkened and discolored. As the callus grows over the injury, the discoloration is covered by clear wood from successive growth sheaths, figs. 5 and 6. Since the vessels produced in the spring are larger and show more clearly than those produced later in the growing season, they are an excellent guide for counting the annual rings. The year in which an injury was made may be ascertained by counting the number of annual rings laid down over the callus above the discolored areas as shown in fig. 7. Cross section of an uninjured elm twig crotch is shown in fig. 8.

CASE STUDIES.—The habit of *Scolytus*

* Acknowledgments are given to C. W. Collins, who encouraged and guided the work; to the late L. H. Worthley and to E. G. Brewer, who provided material assistance; to William Middleton who suggested classifying crotch injuries according to the years in which they were made; and to G. J. Baetzhold for the photography.

FIG. 1.—*Scolytus multistriatus* beetle in elm twig crotch. ×5.

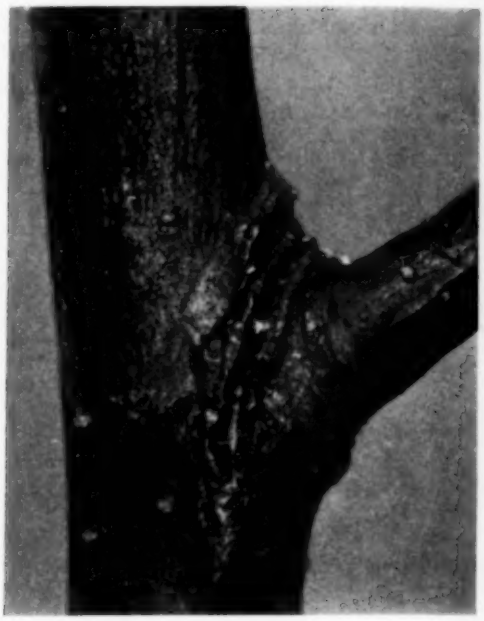

FIG. 3.—Characteristic injured elm twig crotch scar, external view. ×4.

multistriatus of boring into crotches has been called "feeding." This term appears to be substantiated by tests in which 443 *S. multistriatus* adults caged without food or water in cloth covered glass jars lived 2.2±0.4 days (standard error of the mean), while 47 beetles caged with recently cut twigs, on which they fed, lived 7.6±2.6 days. The beetles used in this test were obtained from elm logs from

FIG. 2.—Recent callus formation of wound tissue about an injured elm twig crotch. ×4.

FIG. 4.—Uninjured elm twig crotch, external view. ×4.

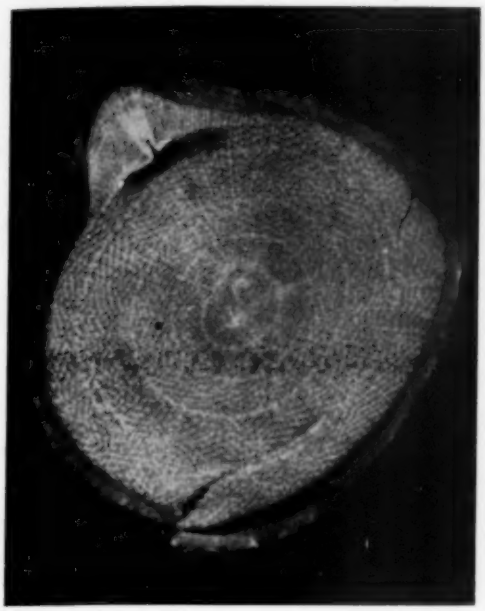

FIG. 5.—Cross sectional view showing discoloration in current or preceding season of an elm twig crotch, the result of feeding by *Scolytus multistriatus*. ×5.

FIG. 7.—Cross section of an elm twig crotch showing a 4-year-old injury. ×5.

indoor cages shortly after they had emerged and hence had no opportunity to feed before the trial.

Two hundred and 10 beetles of each sex of *Scolytus multistriatus* were confined in groups of 3, 6 or 12, in large glass bell jars with fresh elm twigs and logs. The average number of injuries per beetle

FIG. 6.—Sectional view of an elm twig crotch showing a discolored and a more recent injury. ×3.

FIG. 8.—Cross section of an uninjured elm twig crotch. ×4.

during the time of confinement, 7, 10 and 14 days, is given as follows:

	MALE	FEMALE
Twig injuries	0.91	1.03
Log injuries	0.13	0.33

FIELD OBSERVATIONS.—In the field most of the injuries were found to have been made in twig crotches that were located in the upper and outer parts of the trees. On the basis of our observations it would seem that probably one or more injuries are caused by the feeding of *Scolytus multistriatus* in most of the elm trees in the area within a 40-mile radius of New York, N. Y. Trees growing near material from which beetles had emerged showed a greater number of feeding scars than trees that were farther away. However, a variation in the number of injuries has been observed between different trees, even when the trees were growing close together.

Feeding injuries have been found in the following species of elm trees: American, *Ulmus americana* L.; English, *U. procera*, Salisb.; and red or slippery, *U. fulva* Michx.

Branches have been cut from the trees and the crotch injuries classified according to the year in which feeding occurred, in the manner described above. All of the twigs in 218 apparently healthy elm trees, ranging in size from 3 to 8 inches in diameter at breast height, were examined for crotch injuries. The trees were selected without regard for the abundance of *Scolytus multistriatus* in the immediate vicinity. The results obtained by examining the crotches of the twigs from these trees are presented in fig. 9. The number of trees, locations and dates of examination given in fig. 9 are presented in table 1.

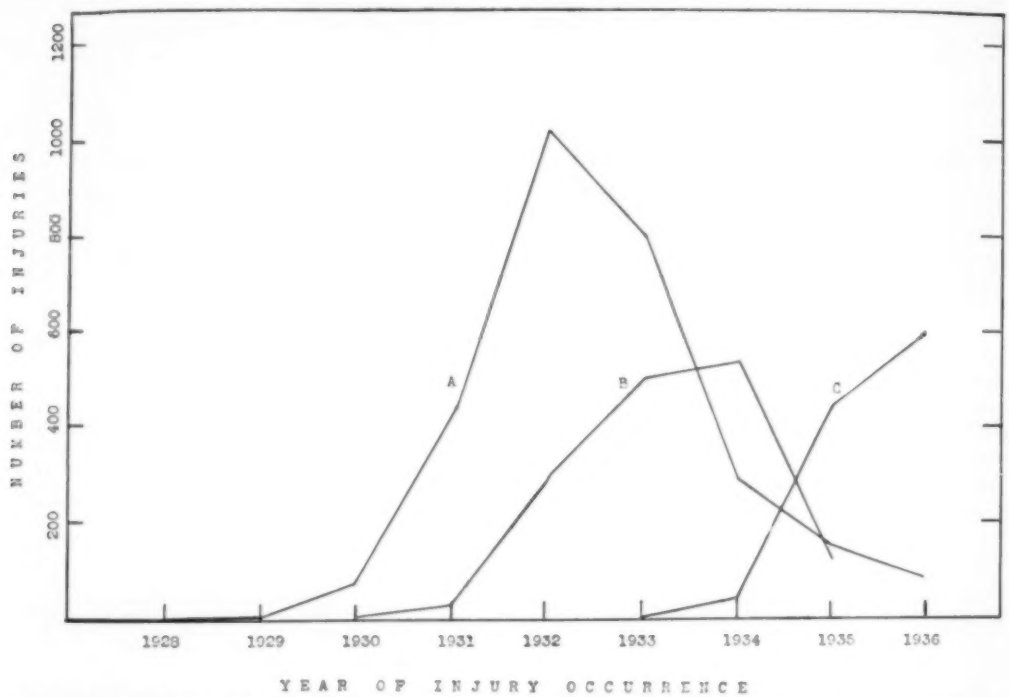

FIG. 9.—Numbers of twig-crotch injuries made in elm trees by the smaller European elm bark beetle, *Scolytus multistriatus: A*, from 139 trees, examined in 1937, in 15 locations in northeastern New Jersey and southern New York; *B*, from 47 trees, examined in 1936, in 10 locations in northeastern New Jersey; *C*, from 32 trees, examined in 1936, in 8 locations in West Virginia.

Table 1.—Locations and dates of examination of 218 elm trees.

TREES	LOCATIONS	DATES EXAMINED
47	Northeastern N. J. (10 locations)	1936
32	West Virginia (8 locations)	1936
139	Northeastern N. J. and southern N. Y. (15 locations)	1937

In fig. 9 the number of injuries is given by the ordinate; the year in which feeding occurred is given by the abscissa.

The curves show, except from the West Virginia trees, increases in the number of injuries followed by decreases. The decreases may be resulting, in part, from the removal by the Dutch Elm Disease Eradication Unit (Worthly 1936, Dodd 1938) of large numbers of elm trees that were suitable for the reproduction of *Scolytus multistriatus*. Other factors such as climate may have contributed to a reduction in the number of beetles and therefore to a decrease in the number of feeding scars.—10-15-38.

LITERATURE CITED

Collins, C. W., W. D. Buchanan, R. R. Whitten and C. H. Hoffmann. 1936. Bark beetles and other possible vectors of the Dutch elm disease, *Ceratostomella ulmi* (Schwartz) Buisman. JOUR. ECON. ENT. **29**: 169–76.

Dodd, H. J. 1938. Current accomplishments in Dutch elm disease eradication. Proceedings National Shade Tree Conference **13**(1937): 150–9.

Worthley, L. H. 1936. Progress in Dutch elm disease eradication. JOUR. ECON. ENT. **29**: 176–81.

Spraying Woodlands With an Autogiro for Control of the Gypsy Moth

S. F. POTTS,* *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Some of the principal difficulties previously encountered in airplane dusting over forests were inability to operate successfully over rugged, broken topography, the scarcity of suitable landing fields, the danger to pilot and plane, inability to obtain good adherence and to control the dust, and the low percentage of available dusting hours, the average being from 13 to 25 per cent of the total amount of daylight. Many of these obstacles may be overcome through the use of more slowly moving aircraft. Much experimental work, however, remains to be done, particularly in the construction of the aircraft itself, the perfecting of mixing and distributing devices, and the improvement of spray mixtures to permit liquids as well as dusts to be used.

In 1927, experiments were performed with dust adhesives and carriers with the object of increasing the efficiency and reducing the cost of application. It was learned that when dusts coated with drying oils were released from an airplane, considerable oil dried before reaching the foliage and, if sufficient oil was added materially to increase adherence, clogging of the releasing apparatus resulted. Investigations along these lines have been continued and it is planned to publish the results in the near future. Methods of mixing oil mists and dust particles have been studied, and a concentrated spray mixture using water as a carrier and oil as an adhesive has been developed. Considerable work has been done in developing apparatus for distributing the concentrated mixtures from airplanes and autogiros.

Preliminary tests with an airplane were made during the winter and spring of 1935, and early in the summer of the same year an autogiro was used for a short time in experimental work. To the writer's knowledge, the first woodland spraying from an autogiro was conducted on April 21, 1936, when a 5-acre stand of red pine near Providence, R. I., was treated with a mixture of water, lead arsenate and linseed oil in the ratio by weight of 1.6–1–0.4 respectively.

DEVELOPMENT OF APPARATUS.—In 1935 two types of spraying apparatus were tested. The first consisted of a strong tank for holding the liquid, located in the cockpit of the aircraft. From this a short pipe 1½ inches in diameter led to a 1-inch pipe 26 feet long attached beneath the wings of the aircraft. The lower side of

* The writer is indebted to various members of the New Haven, Conn., laboratory of the Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine, especially L. D. Casey, for suggestions and help in carrying out the experiments of 1936; to A. F. Burgess of the Division of Gypsy Moth and Brown-Tail Moth Control for furnishing materials and financing the autogiro for these experiments; to Jesse K. Fenno and Donald Whittam, owner and pilot of the autogiro, respectively; and to Karl O. Lange, then of the Massachusetts Institute of Technology, for advice and help in the development of distributing apparatus, and the loan of an airplane for preliminary work in 1935.

this pipe was perforated with one-eighth to one-fourth inch holes. When attached to an airplane, which traveled at a speed of 60 to 100 miles per hour, a cloud of fine mist 60 feet in width was obtained. When attached to an autogiro, which traveled at a slower speed, a relatively coarse deposit resulted. The flow from the storage tank to the perforated pipe was by gravity. Tests made on the ground indicated that where pressures of two to four atmospheres were applied to the surface of the liquid in the tank a fine mist was still obtained through the perforations by later. The rotating screen produced a finer spray than the rotating disc when revolving at 1,500 to 3,000 revolutions per minute, and these speeds were developed when the autogiro traveled at from 38 to 50 miles per hour.

Although these rotating devices were not entirely satisfactory, it is believed that they represent an important step toward perfecting the distributing apparatus. The rate of flow should be coordinated with the speed of the aircraft, and it may be found that a certain amount of pressure should be applied to

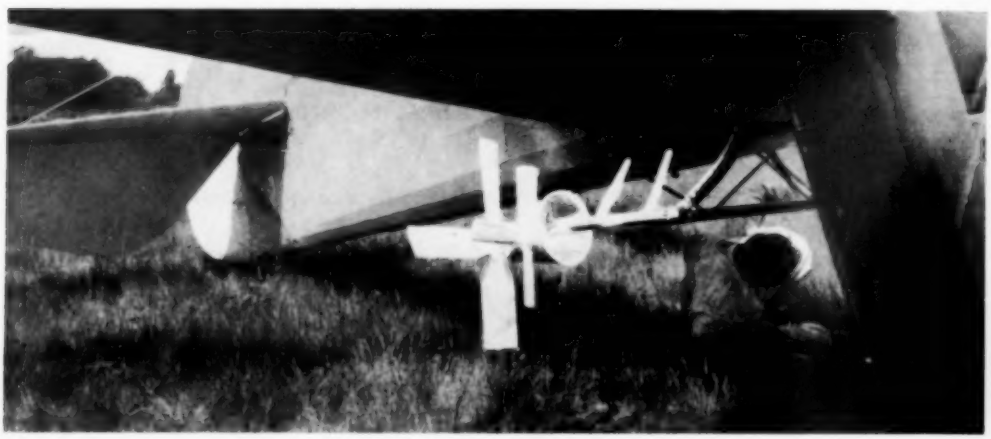

FIG. 1.—Revolving cone-shaped screen, placed back of the feed pipe. The two propellers turn in opposite directions.

the action of the propeller blast from the airplane.

The second apparatus tested used a rotary device to atomize the liquid. This consisted, in one case, of a slightly cone-shaped propeller-driven metal disc from the periphery of which the liquid was thrown off with tremendous centrifugal force. The liquid was delivered to the disc by a pipe the end of which was fully open. After leaving the disc the liquid was struck by a second (larger) propeller, free moving on the same shaft, but rotating in the opposite direction. This helped further to break up the liquid. One of these devices was attached to the struts on each side of the autogiro at the outer edge of the propeller blast. In the other case a three-sixteenths to one-fourth inch mesh, cone-shaped wire screen replaced the disc, fig. 1. Both the disc and the screen were used in experiments performed in 1936, which will be discussed

the surface of the liquid in the tank in order to obtain the best results.

The autogiro used in these experiments could carry a maximum load of only 400 pounds of insecticide and flew at a speed of 38 to 50 miles per hour at a height of 20 to 35 feet above the tree tops, fig. 2. Aircraft especially adapted for this type of work should be built to carry a load of at least 1,000 pounds of insecticide and be capable of flying at speeds as low as 25 miles per hour and of taking off from, and landing in, small areas.

MIXING THE INSECTICIDE.—In the preliminary experiments the insecticides were mixed in a 10-gallon metal tub, but in 1936 a power sprayer was used to mix the concentrated liquid and to pump it into the storage tank in the autogiro.

In the experiments of 1936, 1 part by weight of lead arsenate or calcium arsenate was mixed thoroughly with 2.1 parts of water and then 0.4 part of fish oil was

added. Such a mixture weighed 10 pounds per gallon. In the derris–water–oil mixture, at a ratio of 1–6–0.4 parts, respectively, the weight was 9.5 pounds per gallon. The derris had a 4-per cent rotenone content. With given weights of lead arsenate or calcium arsenate the fluidity of the mixture varies considerably with the brand of arsenate used, and consequently the quantity of water in the mixture must be varied to produce a given degree of fluidity. After the ingredients of these concentrated sprays were thoroughly mixed no appreciable settling occurred under 2 hours. This allowed sufficient time to utilize a load of the spray mixture and eliminated the necessity of having an agitator in the storage tank of the aircraft.

FIG. 2.—Autogiro delivering spray mist above the canopy.

EXPERIMENTS IN SPRAYING, 1936.—Nine plots of 10 acres each (660 by 660 feet) located in the township of Freetown, Mass., were sprayed in the spring of 1936 from an autogiro for experimental control of the gypsy moth, *Porthetria dispar* (L.). The plots were located in an oak type forest composed largely of scarlet oak, *Quercus coccinea*, and white oak, *Q. alba* with the former species predominating. The trees ranged from 15 to 40 feet in height and formed a fairly dense crown canopy. The topography varied from level to slightly rolling. The four corners of the plots were marked by orange-colored flags attached to long bamboo poles which were fastened to the upper part of the trunks of tall trees. The flags were well above the main canopy of foliage. A line of white flags 100 feet apart was placed through the middle of each plot. When the first three plots were treated 9 per cent of the larvae were in the first instar, 71 per cent in the second instar and 20 per cent in the third instar. On June 8, 8 per cent were in the second instar, 37 per cent in the third instar and 55 per cent in the fourth instar. On June 10, the last day of treatment, 36 per cent of the larvae were in the third instar and 64 per cent in the fourth instar. The extent of defoliation before and after treatment in the treated area was compared with that in a 3-acre untreated area of comparable growth nearby. Data concerning the nine 10-acre sprayed plots are given in table 1.

Visual estimates were made of the defoliation in the plots at the time of treatment and at the end of the feeding period. It will be noted that in the arsenical plots

Table 1.—Data concerning the 1936 spraying experiments with an autogiro, Freetown, Mass.

Plot No.	Visible Egg Clusters Per Acre Above Ground	Date of Treatment	Insecticide	Quantity of Spray Applied per Acre		Insecticidal Deposit			Visual Estimate of Defoliation			Precipitation, Inches	Per Cent of Deposit Lost by Weathering*
				Pounds of Insecticide	Gallons of Total Mixture	On Ground	On Foliage		At Time of Treatment, Per Cent	At Time of Pupation, Per Cent	Following Treatment, Per Cent		
						Pounds Per Acre	Pounds Per Acre	Micrograms Per Sq. In.					
1	1,161	May 27	Lead arsenate	15	5	1.9	13.1	132	5	14	9	4.8	14
2	731	May 27	Lead arsenate	20	7	2.2	17.8	172	5	12	7	4.8	14
3	1,634	May 27	Lead arsenate	30	10	5.5	24.5	280	5	11	6	4.8	14
4	1,333	June 8	Lead arsenate	15	5	1.8	13.2	125	10	16	6	4.8	14
5	700	June 8	Lead arsenate	20	7	2.1	17.9	165	10	15	5	4.8	14
6	946	June 9	Lead arsenate	30	10	4.0	26.0	245	10	14	4	4.8	14
7	1,161	June 10	Calcium arsenate	20	7	2.6	17.4	150	17	22	5	4.8	14
8	1,118	June 10	Calcium arsenate	28	9	3.6	24.4	165	15	16	1	4.8	14
9	946	June 10	Derris	27	21	4.0	23.0	—	14	25	11	4.8	50†
Check	1,200	—	—	—	—	—	—	—	5 to 10	90	80 to 85	4.8	—

* The oil in the mixture coated the derris particles, greatly reduced the deterioration by light and air, and greatly increased the adherence. In the case of uncoated particles in plots sprayed from the ground, one-fourth inch of rain removed approximately 80 per cent of the derris from the foliage.
† Estimated

the defoliation following spraying ranged from 1 to 9 per cent. In the derris plot the defoliation after the treatment was 11 per cent. The check plot was 90 per cent defoliated at the end of the feeding period.

A method for determining quantitatively the degree of feeding involves the measurement of the dry weight of frass or excrement which falls to the ground. Wooden frames (3 by 3 feet) with cloth bottoms supported by four short stakes were placed at regular intervals throughout the plot, fig. 3. The frass collected from these daily was weighed and the figures obtained converted into leaf area by a method which will be discussed in another paper. The results of this quantitative study of feeding are presented graphically in fig. 4. With feeding in the check plot rated as 100 per cent, the amount of feeding, expressed in percentages, in each plot is shown before and after the treatment.

Distribution of the spray in different parts of all the plots, with the exception of plot 9, was fair, though not nearly so good at this stage of development as with ground spraying. The distribution from upper to lower portion of the crown was excellent, and often the spray was sufficiently atomized to cover an entire leaf completely. Where an uneven distribution was obtained this may have resulted from any one of the following causes: Imperfections in the distributing apparatus, high speed of the aircraft, variability of wind direction and velocity, inability of the pilot to distinguish the treated from the untreated areas and the relatively small size of the plots. A number of these obstacles may be overcome through further experiments.

Two collections of leaves were made in the eight arsenical plots, one immediately after treatment and the other several weeks later, after 4.8 inches of rainfall. Each plot was sampled by taking 45 to 90 leaves from the upper, middle and lower portions of each of 15 trees. These collections were made to determine the uniformity of distribution throughout the stand at different levels in the crown canopy, and the loss by weathering. In general, the distribution was fairly uniform throughout most of the plots. Leaves having slightly better than average coverage are shown in figure 5. There was a

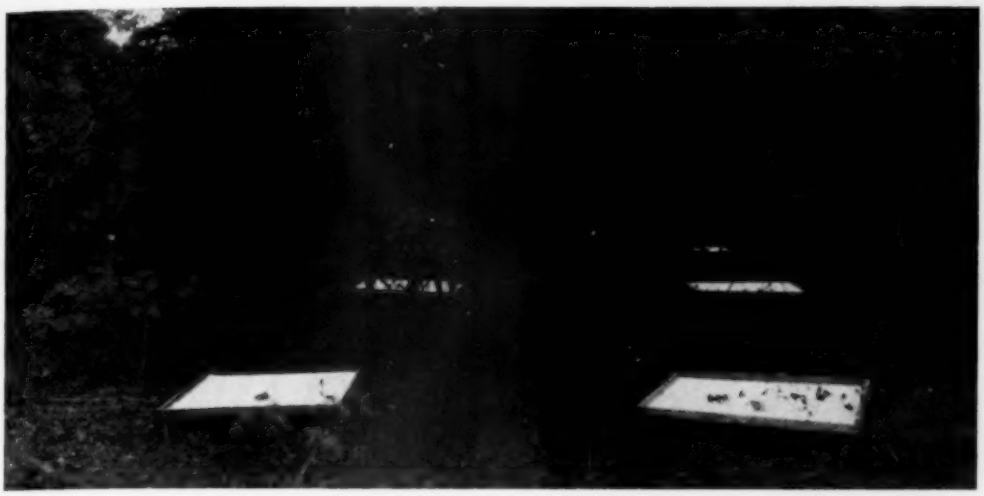

FIG. 3.—Cloth-bottom trays, 3 by 3 feet, used for recovery of frass and larvae.

slightly heavier deposit in the upper part of the crown, but this is highly desirable for it is very important to protect the upper or growing part of the tree from defoliation. Leaves at the top of the tree are thicker and heavier per given area and therefore should receive a heavier insecticide deposit than those on the lower branches. Loss of insecticide on the foliage after 4.8 inches of rain was only 14 per cent in the arsenical plots as compared to 40 to 55 per cent in the case of plots sprayed with lead arsenate and fish oil from the ground in the ordinary manner. The deposit per given leaf area was from 30 to 40 per cent greater than in the case of ground-sprayed woodlands. In order to determine the deposit of insecticide on the ground, paper towels clipped to cardboards were placed at regular intervals throughout the plots. It was determined that about 13 per cent of the insecticide was wasted on the ground. In ordinary spraying from the ground this loss is often as high as 50 per cent.

The landing field was located about 8

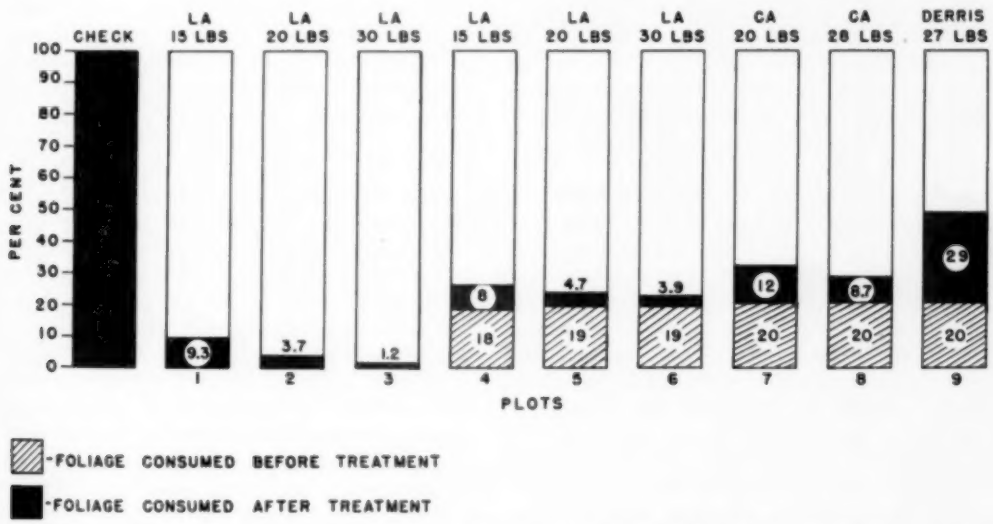

FIG. 4.—Quantitative measurement of the amount of feeding in the treated plots as compared to the check plot. In plots 1, 2 and 3 the quantity of feeding before treatment was negligible. Treatments were with lead arsenate, calcium arsenate and derris.

miles from the plots. Approximately one-third of the total flying time was spent over the plots, two-thirds of the time being used in flying to and from the landing field. Location of the landing field and the "pay load" capacity of the aircraft are important factors in determining the cost of treatment. The cost of the experimental application of insecticides, exclusive of materials and labor employed in laying out and marking the plots, was approximately $8 per acre. This figure must be greatly reduced to render woodland spraying economically practicable. This should be possible, however, when apparatus and flying equipment are perfected and large areas are treated. Other things being equal, the cost of treatment as measured in terms of flying time and cost of insecticide is directly proportional to the quantity of insecticide applied per acre. The loads carried by the autogiro ranged from about 250 to 350 pounds, and from two to three trips, depending on the number of pounds deposited per acre, were required to spray each of the arsenical plots. Six trips were required to spray the derris plot. The average time required for each trip was 23 minutes.

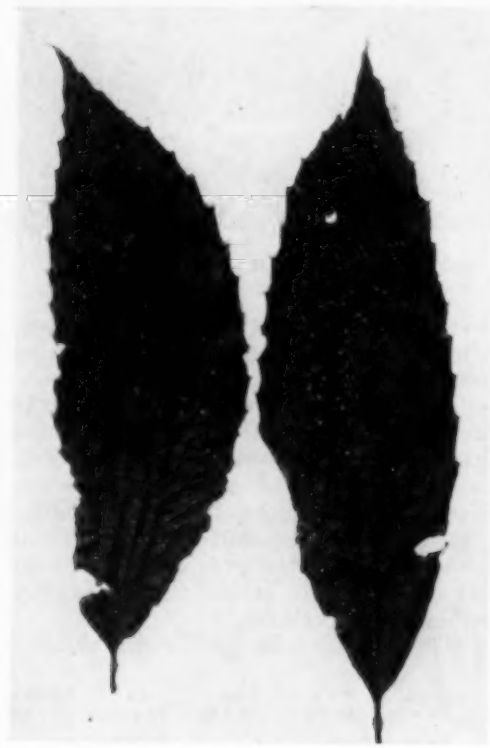

FIG. 5.—Distribution of residue of lead arsenate, water and oil on leaves from a chestnut sprout. (Slightly better than average coverage.)

Each insecticide swath was from 60 to 100 feet wide in preliminary tests. In spraying the plots it was decided to overlap the swaths in order to obtain better coverage, so the pilot of the autogiro attempted to fly on imaginary lines 50 feet apart. At the time the first three plots were sprayed the wind velocity ranged from 8 to 15 miles per hour, whereas during the spraying of the remaining plots it was from 3 to 8 miles per hour. When wind velocity exceeded 12 miles per hour it was difficult to control the spray mist, but at lower wind velocities satisfactory results were obtained. In this connection it is interesting to note that in dusting experiments performed with an airplane in 1926 and 1927 satisfactory results were not obtained when the wind velocity exceeded 5 miles per hour. The strong down current created by the horizontal rotors of the autogiro is of assistance in forcing the mist of spray materials downward, particularly when it is close to the tree tops.

SUMMARY AND CONCLUSIONS.—Experimental work conducted over a period of 9 years on dusts and sprays included the development of a concentrated spray mixture which can be released from aircraft in the form of a mist.

Apparatus has been developed for distributing this concentrated spray mixture from aircraft. It is believed that important steps have been taken toward perfection of such apparatus.

Experiments conducted in 1936 in spraying woodland plots located in Freetown, Mass., from an autogiro for the control of the gypsy moth demonstrated the possibility of using this type of aircraft for the control of certain leaf-eating forest insects where the contour and regularity of the land is favorable.

The autogiro has the following important advantages over the conventional airplane for treating small, broken woodland areas: It is capable of flying at a much slower speed, turning in a smaller area, and landing and taking off from a smaller field, and it is safer to operate. For large, flat areas the airplane has the advantages of greater speed, greater load-carrying capacity and equipment more readily available for landing on water.

Aerial spraying has the following advantages over aerial dusting: There is less drift, a heavier deposit and better adherence of the insecticide, and the number of available working hours is greater. Spraying can be done when the wind velocity does not exceed 12 miles per hour, whereas dusting cannot be satisfactorily carried on unless wind velocity is less than 5 miles per hour.

Favorable results were obtained against the gypsy moth with concentrated mixtures of lead arsenate or calcium arsenate with water and fish oil released from an autogiro. The oil was added as a sticker. The insecticidal spray mixture was approximately 100 times more concentrated than ordinary lead arsenate spray, and only 5 to 10 gallons were required per acre as compared to 450 to 650 gallons of the ordinary mixture used in ground spraying.—10-26-38.

Relation of Number of European Corn Borers Per Infested Corn Plant to Percentage of Plants Infested

L. H. PATCH,* *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Fall surveys to determine the abundance of European corn borer larvae, *Pyrausta nubilalis* (Hbn.), in field corn have been conducted in parts of Ohio, Michigan and New York since 1925. In the conduct of these surveys two methods have been followed. Some entomologists have estimated the intensity of infestation by counting the number of infested stalks out of a given sample of plants in each field examined and expressing this number as a percentage of the sample. Their basis for comparing borer abundance is the number of infested plants per 100 plants in the field. Other investigators have determined the average number of borers per stalk contained in a sample of infested stalks as well as the percentage of plants infested. This method has been described in a recent publication by Meyers & Patch (1937). With these additional data available the basis for comparing borer abundance is the number of borers per 100 plants in the field. This number is the product of the number of infested plants in 100 and the number of borers per infested plant.

The first method requires only an external examination of the cornstalks for evidence of borer feeding. Broken tassels with tunneling of the tassel stalk, masses of frass protruding from entrance holes, and the occasional presence of the borer between the stalk and the dried-up leaf sheaths near the base of the stalk are the usual signs of infestation. The second method for estimating borer abundance is considerably more time consuming than the first method owing to the necessity of dissecting samples of infested plants to count their contained borers. The second method becomes necessary when all the plants are infested with borers. Under such conditions, differences in the density of borer population are indicated only by the numbers of borers in the plants.

As is shown subsequently, there are more borers per infested plant when a larger percentage of plants is infested than when a smaller percentage is infested. The relationship is linear. If the relation between borers per infested plant and percentage of plants infested could be determined as varying within relatively narrow limits from year to year and from locality to locality, the number of borers per infested plant for a given percentage of plants infested might be estimated on the basis of its known regression on the percentage of plants infested and multiplied by the determined percentage to obtain an estimate of the number of borers per 100 plants. Thus, with this correction to the data obtained by estimating borer abundance by the first method the requirements of accuracy for some purposes might be fulfilled quite as well as by estimating abundance by the more time-consuming second method. With this thought primarily in mind the data obtained from 1926 to 1936 from Ohio, Michigan, and New York were

* The author gratefully acknowledges the encouragement and assistance of W. A. Baker during this study, and the preparation of the figure by Ray T. Everly. The original field data from surveys conducted under the direction of D. J. Caffrey, K. W. Babcock and A. M. Vance were used as a basis for the study.

analyzed to determine the degree of variation in the relation between borers per infested plant and percentage of plants infested.

METHODS OF ANALYSIS.—When samples of plants from experimental plots of corn have been dissected, a tendency has been noted for the borers to decrease in numbers with an advance in the season. Upon becoming full-fed many borers leave their burrows in the upper, drier sections of stalks to bore into the lower internodes. In so doing many doubtless wander to the ground and fall prey to mice, ants and birds. For example, from successive samples of plants from 24 strains of field corn planted on May 5 and 12, 1931, it was determined that 15.1 per cent of the borers disappeared between August 20 and September 3 and an additional 7.7 per cent between September 3 and 28. When plantings were made May 19 and 25 no borers disappeared between August 20 and September 3 whereas 10.3 per cent disappeared between September 3 and 28.

Hence, to correct for any extensive migration and disappearance of the borers in the fields of the area-wide surveys, the original field data from each of the 11 annual surveys were grouped first by states and then according to the date of record. The fields surveyed between August 10 and 31 were arbitrarily placed in one group. The other groupings comprised the fields surveyed between September 1 and 10, between September 11 and 25, and between September 26 and October 15. Within each of these major groups the data were further grouped according to the percentage of plants infested. These subgroups are given in the first column of table 1. Then the number of infested plants dissected and the number of borers counted from them were totaled for all the fields in each subgroup for each annual state survey.

For example, the number of infested plants dissected in Ohio between August 10 and 31 and the number of borers from them were further totaled for all the fields having from 0.2 to 3.4 per cent of the plants infested that were surveyed in the years when other fields in the same percentage group were surveyed between September 1 and 10. Then two similar sets of totals were obtained for fields surveyed between August 10 and 31, one for the years when other fields were surveyed between September 11 and 25 and the other for the years when other fields were surveyed between September 26 and October 15.

Then corresponding sets of totals were obtained for all the fields surveyed between September 1 and 10, between September 11 and 25, and between September 26 and October 15, respectively. With each pair of totals obtained up to this point the number of borers was divided by the number of infested plants to obtain the average number of borers per infested plant. Working with these averages it was determined that the number of borers per infested plant from the fields surveyed between September 1 and 10 in Ohio was 98.6 per cent of the number of borers per infested plant from fields surveyed the same years between August 10 and 31. The numbers of borers per infested plant from the fields surveyed between September 11 and 25 and between September 26 and October 15 were 92.2 and 80.0 per cent, respectively, of the number of borers from fields surveyed the same years between August 10 and 31. In a similar manner ratios were calculated for Michigan and New York except that no field was surveyed after September 25 in any year in these states. The ratios as percentages are given in the first line in table 1. In a similar manner ratios were calculated for each of the other percentage groups in table 1.

DISAPPEARANCE OF FULL-FED BORERS IN THE FALL.—The last column in table 1 gives for each percentage group the mean ratio of the number of borers per infested plant in fields in Ohio, Michigan and New York between September 1 and 10 and in Ohio and Michigan between September 11 and 25 to the number found between August 10 and 31. It may be noted that the means show no trend from the low to the higher levels of infestation. Hence, as the season advanced about as high a proportion of borers disappeared from the plants in the lightly infested fields as disappeared from the plants in the more heavily infested fields.

Because of this finding the available ratios were averaged for each period of dissection for each state even though the data in two cases were lacking for some of the higher levels of infestation. It may be noted from the last line of table 1 that

there were averages of 100.17, 99.24 and 76.64 per cent as many borers per infested plant in the fields of Ohio between September 1 and 10, between September 11 and 25 and between September 26 and October 15, respectively, as there were during the period in August. In Michigan there were averages of 90.53 and 84.49 per cent as many borers per infested plant between September 1 and 10 and between September 11 and 25, respectively, as there were during the period in August. A comparable pair of values based on data from New York is 85.09 and 78.51 per cent.

mate of the number of borers in another lot of plants in August instead of between September 1 and 10. Between August 10 and 31, 496 borers were counted from another lot of 265 infested plants. If all the plants had been dissected in August, it is estimated that 1,563 borers would have been counted from 890 infested plants or 1.76 borers per infested plant. In a similar manner the data from each annual state survey from each level of infestation were recalculated.

THE REGRESSION COEFFICIENTS.—For computing the regression of the number of borers per infested plant, Y, on the per-

Table 1.—Number of European corn borers per infested plant of dent corn found between given dates, expressed as percentages of the numbers found between August 10 and August 31, in Ohio, Michigan and New York, 1926 to 1936, inclusive.

NUMBER OF INFESTED PLANTS OUT OF 100 PLANTS	PERCENTAGES OF BORERS PER INFESTED PLANT (ESTIMATED)*							MEAN OF FIRST 5 PERCENTAGES
	Between September 1 and 10			Between September 11 and 25			Between September 26 and October 15	
	Ohio	Michigan	New York	Ohio	Michigan	New York	Ohio	
Class interval†								
0.2– 3.4	98.6	94.2	87.2	92.2	87.6	76.0	80.0	91.96
3.6– 6.4	96.5	92.7	82.9	97.8	76.2	70.8	69.2	89.22
6.6– 9.4	100.8	81.3	84.1	106.8	90.3	72.1	87.8	92.66
9.6–15.4	98.6	77.8	89.0	101.3	66.5	83.8	72.4	86.64
15.6–21.4	100.0	92.6	79.4	111.3	94.4	72.0	73.8	95.54
21.6–27.4	99.3	76.9	90.4	107.2	95.4	81.8	—	93.84
27.6–33.4	111.3	104.7	85.7	117.1	82.0	93.1	—	100.16
33.6–42.4	102.2	102.0	90.6	78.0	82.2	—	—	91.00
42.6–54.4	99.5	97.5	79.6	95.6	96.7	—	—	93.78
54.6–69.4	94.9	85.6	82.0	85.1	73.6	—	—	84.24
Mean	100.17	90.53	85.09	99.24	84.49	78.51	76.64	91.90

* The bases of these percentages are the numbers of borers per plant found between August 10 and 31.
† The explanation for the omission of the figure 5 after the decimal point in the interval spacing is that since at most only 500 plants per field were examined for infestation, the percentages of infestation can be given only in intervals of 0.2. One, 2, 3, 4 and 5 infested plants out of 500, for example, give percentages of 0.2, 0.4, 0.6, 0.8 and 1.0.

CORRECTING DATA FOR DISAPPEARANCE OF BORERS.—In view of the extensive disappearance of the full-fed borers indicated with the advance in the season, the actual numbers of borers taken from the infested plants during the stated periods were corrected to the numbers estimated to have been present if all the plants had been dissected in August. Taking the fields in New York, in 1926, with from 0.2 to 3.4 per cent of the plants infested as an example, 467 and 406 borers were taken from 299 and 326 infested plants between September 1 and 10 and between September 11 and 25, respectively. From table 1 there were 78.51 per cent as many borers between September 11 and 25 as between August 10 and 31. Therefore, 406×1.27, or 516 borers, gives an estimate of the number of borers in the same plants in August. Similarly 467×1.18, or 551 borers, gives an estimate of the number of borers in another lot of plants in August instead of between September 1 and 10. Between August 10 and 31, 496 borers were counted from another lot of 265 infested plants. If all the plants had been dissected in August, it is estimated that 1,563 borers would have been counted from 890 infested plants or 1.76 borers per infested plant. In a similar manner the data from each annual state survey from each level of infestation were recalculated.

centage of plants infested, X, by the method of least squares 10 pairs of recalculated values, each pair representing one of the subgroups in the first column of table 1, were usually available from each annual state survey. The pairs of values were given equal weight in computing each regression coefficient. Actually more plants were dissected at the lower levels of infestation than at the higher levels. For example, when an average of 1.9 per cent of the plants in the fields were infested an average of 929 infested plants were dissected per State per year to obtain the number of borers contained. Comparable averages for fields where 12.4, 30.1 and 61.1 per cent of the plants were infested are 391, 136 and 96 plants. Intermediate numbers of infested plants were dissected from fields with intermediate percentages of infestation. Hence the data from the highest levels of

Table 2.—Estimated number of European corn borers per infested corn plant for three levels of infestation and the regression of the number of borers, Y, on the percentage of plants infested, X, for Ohio, Michigan and New York in 1926 to 1936, inclusive.

State	Year	Number of Borers Per Infested Plant When the Percentage of Plants Infested Was—			Regression of Y on X
		2.0	25.0	62.0	
Michigan	1935	0.8±0.09	1.17±0.050	1.8±0.11	0.017±0.0028
New York	1936	1.1± .13	1.30± .082	1.7± .18	.011± .0044
Ohio	1930	1.2± .05	1.36± .035	1.7± .09	.008± .0021
New York	1933	1.1± .12	1.39± .077	2.0± .17	.015± .0042
Ohio	1936	1.0± .07	1.48± .042	2.3± .10	.023± .0023
Michigan	1930	1.4± .07	1.51± .041	1.8± .09	.007± .0022
Ohio	1932	1.1± .05	1.55± .032	2.3± .07	.019± .0017
New York	1931	1.3± .07	1.56± .046	2.0± .10	.012± .0025
Ohio	1935	1.3± .07	1.60± .045	2.1± .10	.012± .0025
Michigan	1932	1.3± .06	1.64± .038	2.2± .08	.015± .0020
New York	1934	1.1± .08	1.66± .048	2.6± .11	.025± .0026
Ohio	1931	1.2± .03	1.70± .019	2.5± .05	.021± .0011
Ohio	1933	1.1± .09	1.72± .056	2.8± .13	.029± .0030
Michigan	1934	1.3± .12	1.81± .077	2.6± .22	.022± .0051
Ohio	1934	.9± .10	1.81± .074	3.3± .24	.041± .0052
Michigan	1929	1.3± .04	1.82± .029	2.6± .07	.022± .0016
Michigan	1933	1.3± .20	1.83± .127	2.7± .29	.022± .0069
Michigan	1931	1.3± .08	1.83± .051	2.8± .15	.025± .0033
Michigan	1936	1.1± .05	1.85± .032	3.2± .07	.035± .0017
Ohio	1929	1.2± .09	1.91± .058	3.1± .13	.032± .0031
New York	1935	1.1± .14	1.92± .092	3.3± .20	.036± .0049
Ohio	1927	1.5± .06	2.11± .036	3.1± .08	.027± .0019
New York	1928	1.7± .06	2.13± .039	2.9± .09	.020± .0021
New York	1929	1.6± .13	2.16± .080	3.1± .18	.026± .0043
Ohio	1928	1.5± .09	2.17± .060	3.3± .13	.031± .0032
Michigan	1927	1.2± .09	2.18± .056	3.8± .13	.042± .0030
New York	1932	1.4± .10	2.23± .062	3.7± .14	.038± .0034
Michigan	1928	1.6± .07	2.27± .045	3.4± .10	.029± .0024
New York	1927	1.6± .17	2.31± .110	3.5± .32	.031± .0072
Ohio	1926	1.6± .15	2.33± .096	3.5± .22	.031± .0052
New York	1930	1.9± .10	2.43± .063	3.4± .14	.025± .0034
New York	1926	1.9± .20	2.69± .134	3.9± .32	.033± .0073
Michigan	1926	2.2± .12	2.80± .085	3.8± .19	.026± .0042
Mean		1.34	1.89	2.81	.0245

infestation were based on only slightly more than a tenth of the number of plants available from the lowest levels of infestation. But the difference between the recalculated number of borers and the number estimated from the regression of Y on X was only slightly greater at the highest levels of infestation than at the lowest levels. As measured by the standard error of estimate, the difference was 0.22 of a borer at the highest levels compared with 0.14 of a borer at the lowest levels. Since these differences were of no practical importance, the pairs of values were given equal weight in computing the regression coefficients.

The 33 coefficients of regression of the number of borers per infested plant, Y, on the percentage of plants infested, X, calculated from the data from Ohio, Michigan and New York from 1926 to 1936, ranged from 0.007 to 0.042 of a borer per unit percentage of plants infested and averaged 0.0245 of a borer. The coefficients averaged 8.36 times their standard error and no coefficient was less

than 2.50 times its standard error. Therefore, with 8 degrees of freedom available all the coefficients may be regarded as statistically significant and most of them as highly significant. On the basis of the regression coefficients and the means of efficients are given in the last column. It may be noted that in general the regression coefficients increase in magnitude with increases in the number of borers per infested plant.

The data in table 2 indicate that when

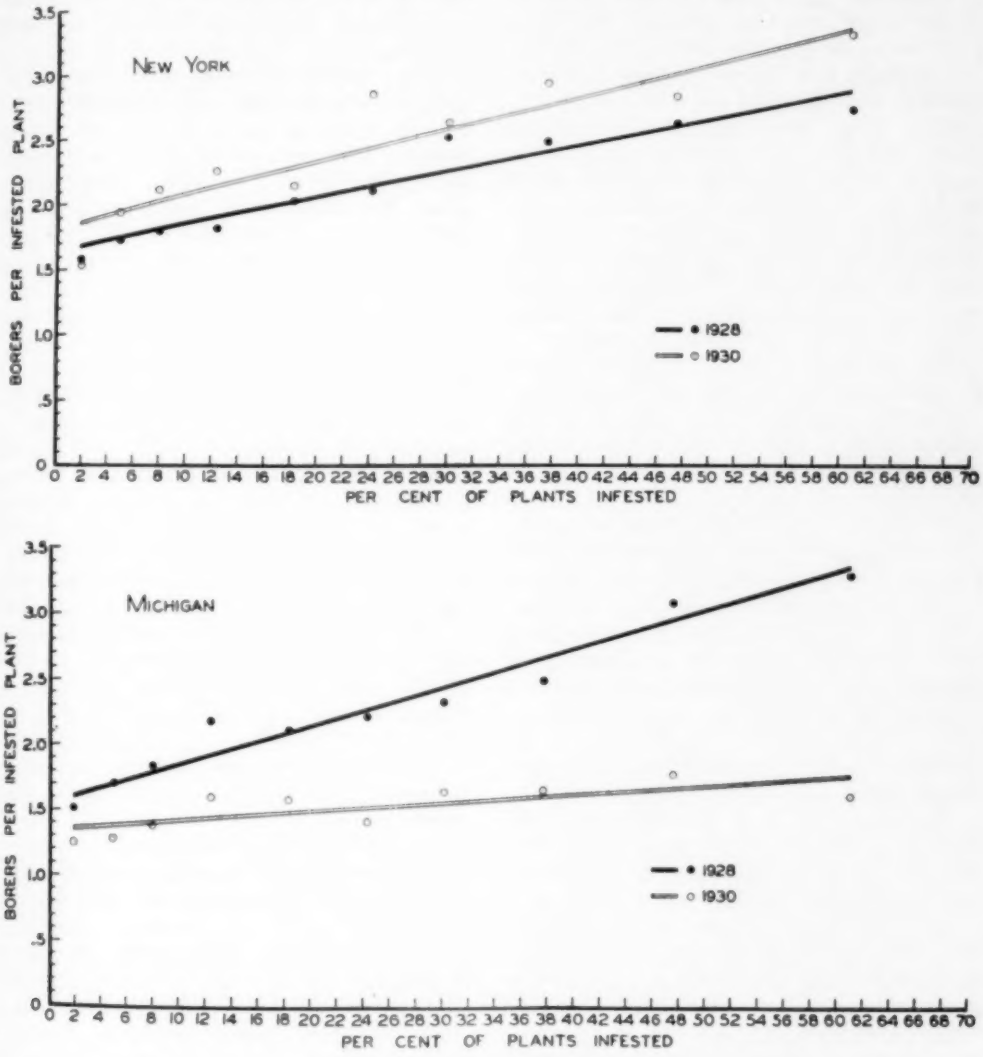

FIG. 1.—Regression of number of European corn borers per infested corn plant on the percentage of plants infested, Michigan and New York, 1928 and 1930.

X and Y, estimates were calculated of the numbers of borers per infested plant for percentages of infestation of 2, 25 and 62. These estimates are given in table 2 and their arrangement depends upon the ascending order of the number of borers per infested plant when 25 per cent of the plants were infested. The regression co-

2 per cent of the plants were infested the number of borers per infested plant ranged from 0.8 to 2.2 and averaged 1.34. The fact that no borers were found in some plants which showed the characteristic signs of borer infestation explains why the borer population averaged less than a borer per plant in some cases.

When 25 per cent of the plants were infested the number of borers ranged from 1.17 to 2.80 and averaged 1.89. When 62 per cent of the plants were infested the number of borers ranged from 1.7 to 3.9 and averaged 2.81.

These data show that not only the slope of the regression line denoting the relation between number of borers per infested plant and the percentage of plants infested but also the level of the line is subject to a wide fluctuation between years and between localities. As an illustration of the variability, the numbers of borers per infested plant are plotted in fig. 1 against their respective plant infestation, the Michigan and New York data for 1928 and 1930 being used. Regression lines were fitted to the plotted points by the method of least squares.

For Michigan both the slope and level of the regression lines in fig. 1 are different in the two years, the level of borers being much higher in 1928 than in 1930. In New York there is little difference in the slope and a small difference in the level of the lines but the level of borers was higher in 1930 than in 1928. It is evident that the variability in the relation between borers per infested plant and percentage of plants infested is too great between years and between localities to permit even a rough estimation of the number of borers on the basis of the relation of this factor to percentage of infestation in the absence of such data from dissected samples of infested plants.

DENSITY OF EGG POPULATION AND NUMBER OF PLANTS INFESTED.—The number of borers per infested plant and the percentage of plants infested are both dependent upon a number of factors operating from the time of egg laying until the maturity of the borers. In a random laying of egg masses on the plants of a field some plants would receive more than one egg mass. The chances of any one plant receiving two or more egg masses would increase with an increase in the number of moths and with a possibly greater attractiveness to moths of some plants than of others. Area-wide data from 655 daily records of eggs laid in 1932 showed that 10.65 egg masses per 100 plants were laid in fields where 10 per cent of the plants received masses compared with 76.50 masses where 50 per cent of the plants received masses. Thus when 5 times the number of plants received masses there resulted 7.18 times as many masses. The increase in the number of egg masses per infested plant with increases in the percentage of plants receiving eggs is the fundamental cause for the positive relationship between number of mature borers per infested plant and percentage of plants infested.

Many of the newly hatched borers are carried by aerial drift and migrate otherwise to adjacent plants and hills. Neiswander & Savage (1931) state that about 50 per cent of the larvae recovered from a given egg deposition had dispersed to hills other than the one on which they originated. The writer infested one plant in each of 32 uninfested hills of corn with one egg mass. The masses were uniform in size. Of the total mature borers recovered in the same hills half were from the plants originally infested and each of the other two plants in the hill gave a quarter of the total.

As a result of the dispersion of young larvae and in the absence of counterbalancing factors, the percentage of plants infested with mature borers would be larger than the percentage infested with egg masses. One such factor is probably a failure of an infestation to develop when egg masses become dislodged by the wind. In an experiment where the fate of egg masses was under observation it was estimated that 44 per cent of the masses were dislodged as a result of a severe wind storm with a light fall of rain during the preceding night.

OTHER FACTORS DETERMINING THE LEVEL OF BORERS PER INFESTED PLANT.—In addition to the foregoing factors, the number of borers per infested plant for given percentages of infested plants is dependent on the number of egg-laying moths, the number of eggs per mass and the number of borers surviving from a given number of eggs or the rate of borer survival. The effect of an increase in the number of moths in increasing the number of borers per infested plant is not proportional to the increase in the moths because a large part of the increase in moths probably increases the percentage of plants infested with mature borers. This conclusion is based on the fact that an increase in the number of egg-laying moths from the number required to lay 10.65 egg masses per 100 plants to the

number required to lay 5 times that number gives a 3.9-fold increase in the percentage of plants infested with egg masses. Since comparisons between numbers of borers per infested plant are for given percentages of infested plants, variations in the number of moths play a relatively small part in the variation of the number of borers per infested plant.

The number of eggs per mass is a rather variable factor. For example, the unpublished data of Babcock show that the number of eggs per mass averaged 15.9 in Michigan, Ohio and western New York in 1930 compared with 14.1 in 1931 and 24.2 in 1932. As between states the variation was not so large.

The rate of borer survival varies principally with the weather, the strain of corn, the developmental stage of the corn plants and the degree of competition among the young borers. As a result of all these and the foregoing factors the level of borers per infested plant for given percentages of infested plants varies from year to year and from locality to locality. As shown in table 2 the variation was found to be as much as 2.75-fold when 2 per cent of the plants were infested and 2.29-fold with an infestation of 62 per cent. In view of these findings, to obtain an accurate measure of borer abundance it is necessary, in addition to determining the percentage of infested plants, to determine the number of borers per infested plant by actual dissections rather than by estimation of the number of borers per infested plant on the basis of its regression on percentage of plants infested.

SUMMARY.—Data are presented giving the estimated numbers of European corn borer larvae per infested cornstalk when 2, 25 and 62 per cent of the stalks were infested in fields of dent corn surveyed in each of the annual state surveys to determine the abundance of the borer in Ohio, Michigan and New York from 1926 to 1936, inclusive. The numbers of borers were estimated on the basis of the linear regression of borers per infested stalk on percentage of infested stalks.

When 2 per cent of the stalks were infested the number of borers per infested stalk ranged from 0.8 to 2.2 and averaged 1.34. Comparable data when 25 and 62 percent of the stalks were infested showed that the numbers of borers ranged from 1.17 to 2.80 and from 1.7 to 3.9 and averaged 1.89 and 2.81, respectively.

The abundance of the borer has been estimated by following two methods. The basis for comparing borer abundance by the first method is the number of infested stalks per 100 cornstalks, or the percentage of infested stalks. By the second method the mean number of borers per stalk contained in a sample of infested stalks is multiplied by the percentage of infested stalks to obtain the mean number of borers per 100 cornstalks.

Since the first method takes no account of the variation in the number of borers per infested stalk, the purpose of the present study was to determine the possibility of obtaining a reliable estimate of borer abundance per 100 stalks by use of an experimentally established regression of number of borers per infested stalk on percentage of infested stalks, in order to eliminate the necessity of making dissections to determine the number of borers per stalk.

In view of the rather wide variation of the coefficient of regression from year to year and from locality to locality it is concluded that a reliable estimate of borer abundance can be made only by following the more time-consuming second method.—10-26-38.

LITERATURE CITED

Meyers, M. T., and L. H. Patch. 1937. A statistical study of sampling in field surveys of the fall population of the European corn borer. Jour. Ag. Res. **55**(11):849–72. 3 figs.

Neiswander, C. R., and J. R. Savage. 1931. Migration and dissemination of European corn borer larvae (*Pyrausta nubilalis* Hubn.). JOUR. ECON. ENT. **24**(2):389–93.

THE Mexican fruitfly quarantine was modified by circular B.E.P.Q. 495 of April 7 requiring sterilization of all grapefruit harvested on and after April 12, 1939, and extending the harvesting season on grapefruit to May 15.

THE oriental fruit moth quarantines of Arizona, California, Nevada, Oregon and Washington have been revised in recent months to permit the entry of bare-rooted host plants, when fumigated, during the dormant period.

Agar-Agar, a New Activator for Nicotine Sprays

S. S. Sharp,* *Louisiana Agricultural Experiment Station, University*

While studying the effects of various supplements in nicotine sprays, it was discovered that agar-agar activated nicotine to a noteworthy degree. The test insect used was the pea aphid, *Illinoia pisi* (Kltb.).

The Experiment.—Agar-agar was used in the sprays at a dilution of 1–500 by weight. A colloidal solution of this concentration was prepared by boiling the agar-agar in the required amount of water until dispersed. Water was added from time to time to replace that lost by vaporization. The spreader and the nicotine were then added to this solution to make the finished spray.

Commercial nicotine sulfate and 95 per cent free free nicotine were utilized as the sources of nicotine. *Neutral Olive Powder* hereafter designated "soap," was used as the spreader.

In these experiments agar-agar was compared with karaya gum as an activator for nicotine sprays. The karaya gum sprays were prepared in a manner previously described (Eddy & Sharp 1937).

In the tests, pea leaves having five or six leaflets were placed in vials of water and the aphids then distributed on the several leaflets. Each leaf was sprayed on all sides with an atomizer to insure thorough wetting of the insects. Mortality records were made at the end of 24 hours. Table 1 details the results of these experiments. The net percentage control was computed from Abbott's formula (Abbott 1925).

Results.—The inclusion of agar-agar in the sprays reduced to one-third the amount of nicotine required to produce toxic effects. When no activator was used, concentrations of more than 1–600 of nicotine sulfate and 1–1425 of 95 per cent free nicotine were necessary to produce equivalent toxicity.

Statistical analysis of the results showed that in only one case was there a significant difference between the activation produced by agar-agar and that by karaya gum. The exception occurred when the two activators were used with nicotine sulfate, 1–1800 and soap, 1–500. No explanation could be found for this difference and the author doubts its validity. Each spray was run with two different concentrations of the spreader, but the only significant differences in toxicity were with 95 per cent free nicotine, and with karaya gum and nicotine sulfate at the different soap concentrations. Again no apparent cause could be ascribed to these differences.

How agar-agar and karaya gum produce activation of nicotine is still a matter of conjecture. It may be stated that the two materials are somewhat similar chemically, as gelose is reported to be the chief constituent of each. Both materials also form negative hydrophilic colloids in water.

It is difficult to disperse either agar-agar or karaya gum in water. If placed in contact with water, karaya gum powder, will, in a period of several hours, absorb many times its weight of liquid to form a gel which may be stirred into water. The powder may be worked into water by hand but this is a slow and laborious process. As reported by Eddy & Meadows (1937), karaya gum may be wet by a light miscible oil and then be dispersed as this mixture is stirred into water. Compton & Kearns (1937) report wetting the gum with ethyl or methyl alcohol before adding it to water. Whatever method be used, it is not easy to get karaya gum powder into water without the formation of lumps. Only a part of the gum goes into colloidal dispersion. A larger part, which eventually settles out, is suspended in water in the form of small flakes and fine particles.

Agar-agar may be best dispersed in water by boiling for about 30 minutes. Water at ordinary temperatures has no effect on the substance. When dispersed in water at a concentration of 1–500, agar-agar produces a homogeneous clear liquid of the consistency of thin molasses. Because it is all in the colloidal state, agar-agar remains evenly distributed throughout an aqueous spray and does not settle to the bottom as does karaya gum.

Inasmuch as cost and difficulty of dispersion render both agar-agar and karaya gum impractical for general use in sprays,

* Now at Iowa State College, Ames.

Table 1.—Comparative effect of agar-agar and karaya gum in activating nicotine sprays against the pea aphid.

COMPOSITION OF SPRAY	NUMBER OF TESTS	NUMBER OF APHIDS	NUMBER OF APHIDS KILLED	PER CENT TOXICITY	NET PER CENT CONTROL
Nicotine sulfate, 1–1800; agar-agar, 1–500; and soap, 1–800	10	176	164	93.18	91.52
Nicotine sulfate, 1–1800; agar-agar, 1–500; and soap, 1–500	10	181	162	89.50	84.88
95% Nicotine, 1–4275; agar-agar, 1–500; and soap, 1–800	10	181	139	76.80	74.92
95% Nicotine, 1–4275; agar-agar, 1–500; and soap, 1–500	10	180	161	89.44	82.40
Agar-agar, 1–500, and soap, 1–800	5	76	20	26.31	14.20
Agar-agar, 1–500 and soap, 1–500	5	73	29	39.73	26.01
Nicotine sulfate, 1–1800; karaya gum, 1–500; and soap, 1–800	10	184	139	75.54	69.60
Nicotine sulfate, 1–1800; karaya gum, 1–500; and soap, 1–500	10	187	170	90.90	86.89
95% Nicotine, 1–4275; karaya gum, 1–500; and soap, 1–800	10	181	106	58.56	55.20
95% Nicotine, 1–4275; karaya gum, 1–500; and soap, 1–500	10	173	136	78.61	64.35
Nicotine sulfate, 1–1800, and soap, 1–800	5	87	17	19.54	6.32
Nicotine sulfate, 1–1800, and soap, 1–500	5	75	23	30.66	14.81
95% Nicotine, 1–4275, and soap, 1–800	5	80	6	7.50	0.00
95% Nicotine, 1–4275, and soap, 1–500	5	85	34	40.00	26.29
Nicotine sulfate, 1–600, and soap, 1–500	6	122	106	86.89	83.89
95% Nicotine, 1–1425, and soap, 1–500	5	101	83	82.18	78.11
Soap, 1–800	5	85	12	14.11	14.11
Soap, 1–500	5	86	16	18.60	18.60
Water	3	57	0	0.00	0.00

it is hoped that further study of this problem may reveal the existence of other activators that are free from such disadvantages.

SUMMARY.—Experiments showed that agar-agar trebled the effectiveness of nicotine sprays on the pea aphid. The activation by agar-agar was equal to that produced by karaya gum. Both agar-agar and karaya gum are difficult to disperse in water and are unsatisfactory for general use in sprays. The dispersal of karaya gum is materially assisted by the use of alcohol and light mineral oils, whereas agar-agar is best dispersed by boiling in water.—10-26-38.

LITERATURE CITED

Abbott, W. S. 1925. A method for computing the effectiveness of an insecticide. JOUR. ECON. ENT. **18**(2):265–7. April.

Compton, C. C., and C. W. Kearns. 1937. Improved control of red spider on greenhouse crops with sulphur and cyclohexylamine derivatives. JOUR. ECON. ENT. **30**(3):512–22. June.

Eddy, C. O., and C. M. Meadows. 1937. Karaya gum in nicotine sprays. JOUR. ECON. ENT. **30**(3): 430–2. June.

Eddy, C. O., and S. S. Sharp. 1937. Effect of different spreaders on thrips control by nicotine. JOUR. ECON. ENT. **30**(3):427–30. June.

THE Pennsylvania quarantine regulations relating to the potato wart were lifted November 15, 1938, from certain eradication areas previously under quarantine in four counties of that state, no such disease having been found in those areas in the past 5 years.

Sarcophaga aldrichi Parker as a Parasite of *Malacosoma disstria* Hbn.*

A. C. Hodson,† *University of Minnesota*

There is no doubt about the true parasitic nature of many Sarcophagids for they have been established as parasites of numerous Arthropods. However, there still seems to be some question with regard to their relation to Lepidopterous larvae. Aldrich (1915) suggests that Sarcophagids may attack caterpillars but he offers no conclusive evidence. The prevailing opinion seems to be that these flies limit their attack to dying and diseased caterpillars. Recently there has been a renewed interest in the problem because of the remarkable numbers of Sarcophagid flies which have been observed in all areas of northern Minnesota where the forest tent caterpillar, *Malacosoma disstria* Hbn., was abundant. Specimens caught in the field and those reared from *M. disstria* were identified as *Sarcophaga aldrichi* Parker. This species was reared first from the forest tent caterpillar by Caesar (1916). He reported that about 90 per cent of the pupae were parasitized by this fly. Parker (1916) described the species from material reared by Caesar. He states, "Except for a few scattered specimens captured in isolated localities, the only records the writer has of the occurrence of this species in abundance have been where there were larvae of either *Porthetria dispar* or *Malacosoma disstria*, especially the latter." The purpose of this paper will be to present evidence of the true parasitic activity of *S. aldrichi*. The intensive life history studies were conducted at Itasca State Park, Minnesota, during the summer of 1937.

Developmental Stages of Host Attacked by Parasite.—The first problem to be investigated was the time in the life cycle of the host when larviposition takes place. For this purpose 100 fifth instar larvae were collected in the field at regular intervals. These larvae were fed in insectary cages until they pupated. As soon as the first cocoons were spun in the field two 100 cocoon samples were taken each day. One lot was caged for the emergence of parasites and moths. The cocoons in the other lot were opened each day and their contents dissected to obtain a record of the seasonal development of the host and the presence of parasites.

No Sarcophagid larvae emerged from any of the cocoons of caterpillars which were collected June 20, the date when the first cocoons were spun in the field. Fig. 1 shows that *Sarcophaga aldrichi* maggots were not present in the samples until after this date. However, they were found in the first samples of cocoons to be collected. It will be noticed that the date, June 22, appears twice on the abscissa in fig. 1. The data corresponding to the first occurrence are based upon a collection of 100 caterpillars, and the data for the second are derived from a collection of a like number of cocoons. The maggots of *S. aldrichi* did not emerge from the former but they were present in small numbers in the latter even though the caterpillars and cocoons were collected at the same time. These observations make it clear that *S. aldrichi* limits its larviposition to the cocoons of *M. disstria*.

Fig. 1 also illustrates the daily record of parasitism by other species of parasites. Two species of Tachinids attacked the active host larvae before pupation time and Ichneumonids oviposited in the pupae. These other parasites were much less important than *Sarcophaga aldrichi*. The reduction in the emergence of Tachinids from the daily collections of cocoons was due partly to the emergence of Tachinid larvae before the samples were taken. However, the apparent decrease in the number of Tachinids and the small number of Ichneumonids is directly related to the activities of *S. aldrichi*. Dead, full-grown Tachinid larvae were found commonly in a host pupa with an active Sarcophagid maggot. The larvae and pupae of Ichneumonids also are killed when they happen to occur in the same host with *S. aldrichi*. The evidence points toward the conclusion that *S. aldrichi* is so intrinsically superior to other para-

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sites that the introduction of exotic species would be impractical.

DEPOSITION OF MAGGOTS AND THEIR DEVELOPMENT.—It is often difficult to observe the larviposition of *Sarcophaga aldrichi* in the field because the flies move from one place to another very rapidly. After many fruitless hours three females were observed while they deposited their maggots. They selected areas where silk was exposed between the edges of folded leaves. A single maggot was deposited quickly after the flies had made a painfully long, careful inspection of the site. Occasionally more than one maggot is found in a host larva or pupa. In a few cases as many as three maggots developed in a single pupa, but instances of this sort were not common.

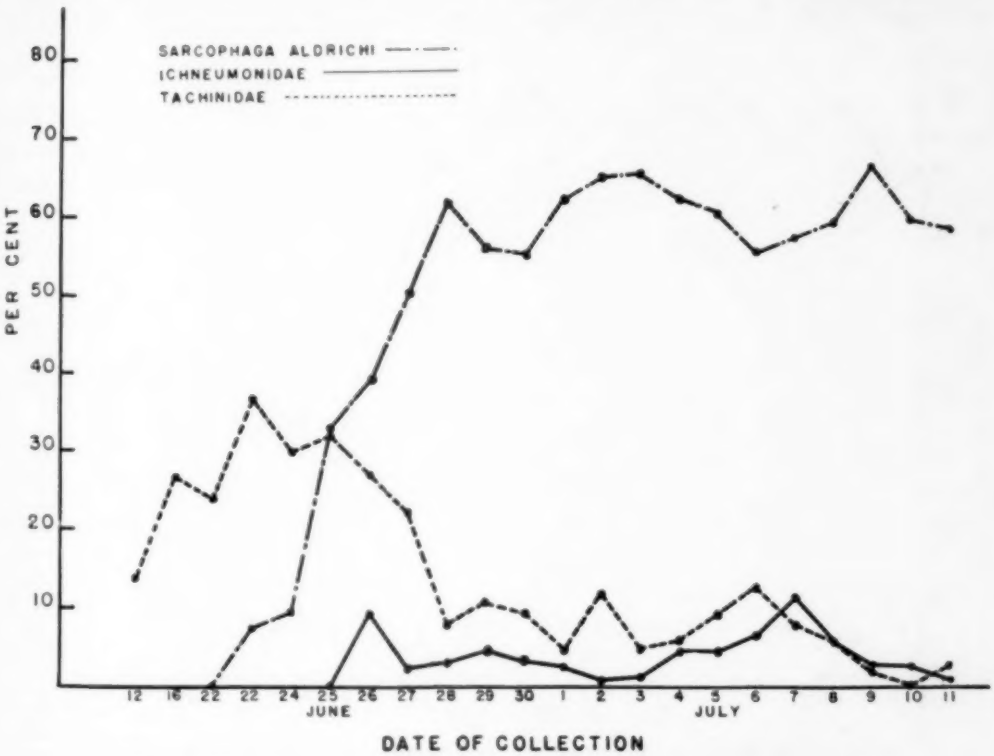

FIG. 1.—The emergence of parasites from daily collections of cocoons expressed in percentage of the total host sample for each date.

The time required for the penetration of the host and the length of the feeding period were determined in the laboratory. Maggots were expressed from field captured flies and were placed on completed cocoons with a camel's hair brush. They required from 2 to 8 hours to penetrate the fibers of cocoons and find the host. The maggots will enter the host at almost any position, even through the prolegs of prepupae. The sequence of events which takes place after the caterpillars start to spin their cocoons can be seen in fig. 2, and the development of the host is illustrated in fig. 3. The data presented in these graphs were obtained from the samples of 100 cocoons which were opened each day. Young maggots are deposited in the cocoons until about the time when the host adults begin to emerge. In three instances active maggots were found in fully developed moths which had been attacked before they could leave the pupal case. The maggots usually feed about 3 to 5 days. The exact time is difficult to determine because the maggots often lie quietly in the host for several days. Under favorable conditions they leave the cocoons about 8 to 12 days after being deposited. This time corresponds rather closely to period of moth emer-

gence, as can be seen by comparing figs. 2 and 3. During the very dry summer of 1936 most of the maggots remained in the cocoons for more than a month. After several days of rain they went to the ground.

Approximately two-thirds of the parasitized host individuals are killed in the pupal stage. There is usually a very small percentage of the cocoon-spinning larvae first and are followed in a few days by the females. Mating pairs can be observed soon after the first female appears. Female flies were captured at frequent intervals and their ovaries were examined for developing eggs and maggots. Those examined June 20, 1937, showed 10 per cent with maggots, 40 per cent with large eggs and 50 per cent with undeveloped eggs. Four days later a sample of 100 fe-

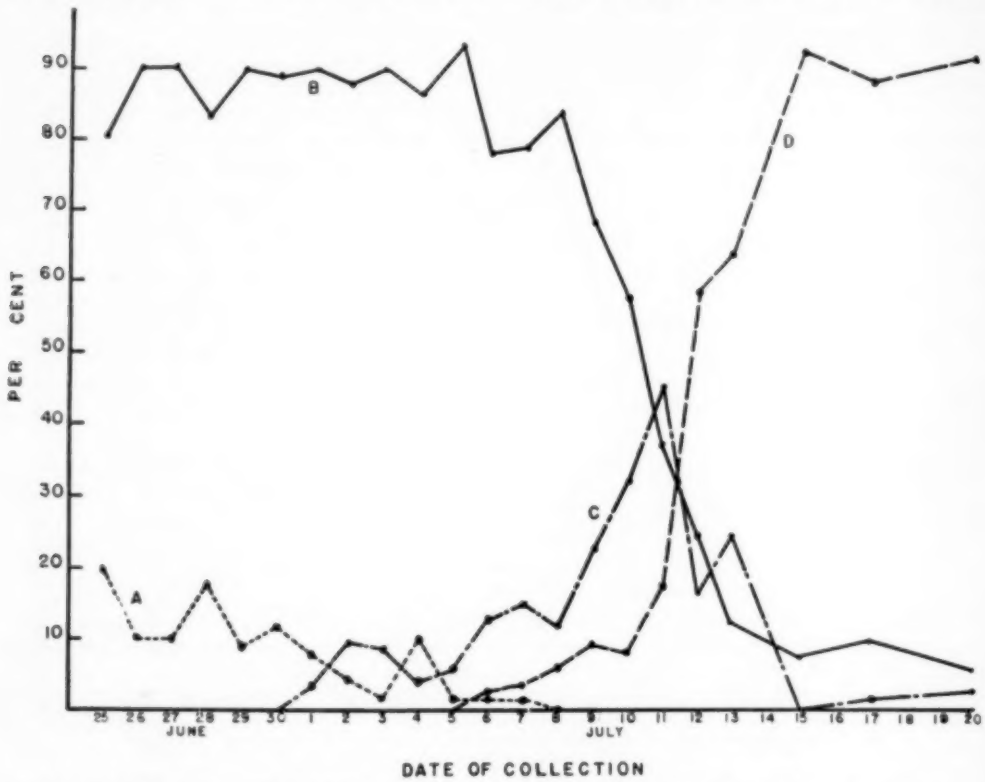

FIG. 2.—The daily progress of the development of the larvae of *Sarcophaga aldrichi*. *A*, per cent of newly deposited maggots in webbing. *B*, per cent of cases in which maggots were in host. *C*, per cent of full-grown maggots lying in cocoons. *D*, per cent of cases in which maggots had left cocoons.

attacked. They are designated in fig. 3 as "larvae." Fig. 3 shows the reason for the high percentage of parasitized pupae. The caterpillars require about 1 day to complete the cocoon, and they spend about 2 days in the prepupal stage. Then they remain in the pupal stage 10 to 12 days. During the relatively long pupal period the flies reach the height of their activity and are most abundant.

LIFE CYCLE OF *Sarcophaga aldrichi* WELL ADJUSTED TO THAT OF HOST.—In 1937 the flies appeared in the field about the last week in May. The males emerge

males gave the following results: 40 per cent maggots, 45 per cent eggs and 15 per cent undeveloped. The maggots were ready to be deposited just at the time the host was pupating. In 1938 the flies appeared two weeks later than in 1937 and pupation of the host caterpillars was also delayed about two weeks. Under insectary conditions females reared from *Malacosoma disstria* required about 16 days for their eggs to be completely developed. Active maggots were present about 20 days after the flies emerged. These intervals of time required for egg and maggot

development agree well with field observations.

Sarcophaga aldrichi does not require other hosts during the latter part of the summer. The maggots form a puparium when they go into the soil during July or early August. They transform into the pupal stage and then enter a diapause which is not interrupted until the following spring. Dormancy is broken only by an exposure to moderately low temperature for at least two months. The unpublished studies of R. F. Anderson have shown that the species will breed in decaying organic material and carrion. Under these conditions a second generation of adults will emerge. As a parasite of the forest tent caterpillar *S. aldrichi* has only one generation a year, and for this reason a second host is unnecessary. However, the scavenger habits make it possible for the species to be present even when the host larvae are not abundant.

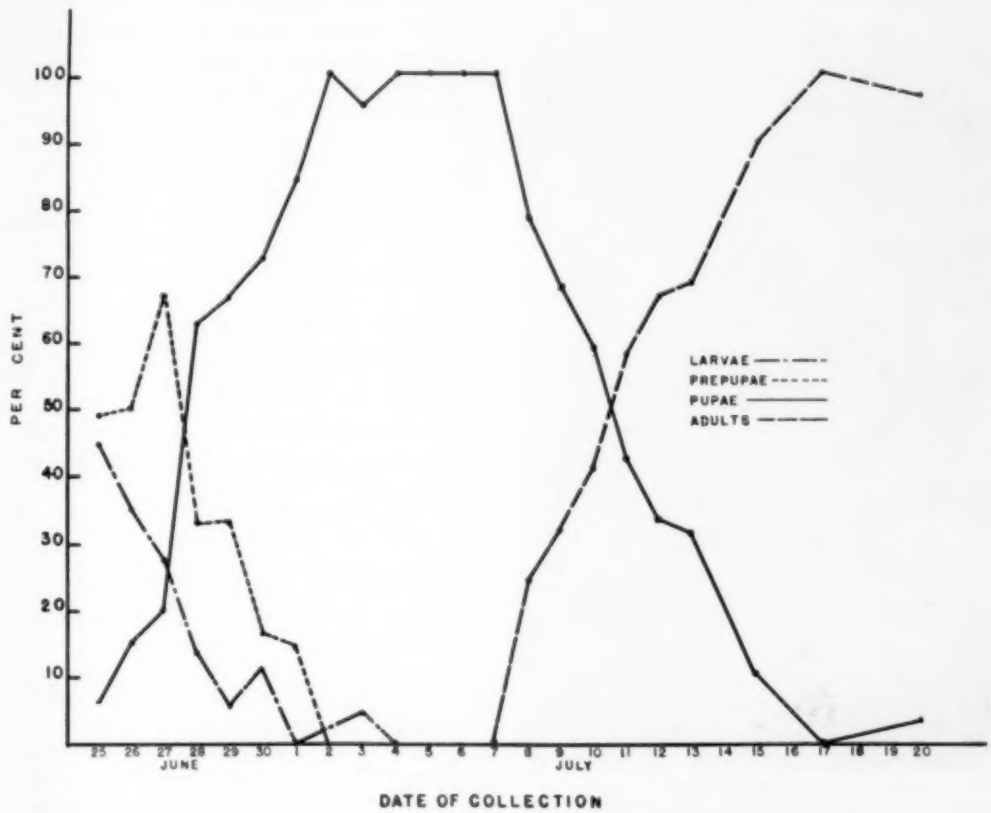

FIG. 3.—The stages of development of *Malacosoma disstria* in the daily collections of cocoons.

SARCOPHAGA ALDRICHI ATTACK NOT LIMITED TO DEAD OR DISEASED LARVAE AND PUPAE.—Previous studies on the Sarcophagids have suggested that they limit their attack probably to dying and diseased caterpillars. Patterson (1911) studied the relation of Sarcophagids to gypsy moth caterpillars and concluded that they could not establish themselves in healthy larvae. Unfortunately none of his species was identified; so it is impossible to learn whether he used *Sarcophaga aldrichi* in his experiments. More recently Gösswald (1934) has investigated the supposed parasitic habit of *S. schützei* which has often been reared from nun moth larvae. He discovered that the flies were attacking larvae either already parasitized by a Tachinid or those dying from polyhedral disease. *S. aldrichi* will develop on decaying organic material of various kinds. For this reason it has been supposed by some to limit its attack

to dying and diseased caterpillars. Some experiments were designed to test this supposition. In one experiment 27 expressed maggots were placed on the cocoons of laboratory reared caterpillars. Sixteen of the maggots succeeded in entering the pupae and developed normally. Moths and one Tachinid emerged from the remaining 11 cocoons. The unsuccessful maggots died in the webbing of the cocoons. Small maggots, deposited in the field, were removed from 25 cocoons. All of the pupae within these cocoons were healthy enough to develop into normal moths. Furthermore, in spite of the abundance of parasitized pupae there is no evidence that the flies were being attracted by diseased caterpillars. The incidence of wilt disease was only a small fraction of 1 per cent of the caterpillar population. It is easy to understand why it might be thought that the flies seek diseased caterpillars or pupae. Immediately after a maggot has penetrated the host it breaks down the tissues by some proteolytic action. The result is a brown, stinking mass which imparts a characteristic stain to the cocoon. The method of feeding is definitely that of a scavenger. The maggots enlarge an opening through the body wall of the host through which they emerge periodically for air. This action is like that of other species when they feed in excrement or carrion. This method of feeding will explain the success of *S. aldrichi* when it enters into internal competition with other species.

FIG. 4.—*Sarcophaga aldrichi* adults are readily attracted to human skin. (Photo by Nagel, U. S. Dept. Ag., Bur. Ent. Pl. Quar.)

It has already been mentioned that *Sarcophaga aldrichi* will attack the host after it has already been parasitized by other species. One might be led to believe that the Sarcophagid would show a distinct preference for such host individuals. However, the evidence indicates that the host selection is not limited to pupae and prepupae which have been parasitized previously. There was no evidence of multiple parasitism in many samples of pupae which were dissected. It is improbable that one would fail to observe the presence of other parasites because apparently they are not devoured by the Sarcophagids. The dead larvae of Tachinids and Ichneumonids often remain in the host at the time when the Sarcophagids have finished feeding. The laboratory experiments described above also establish the fact that *S. aldrichi* will develop in perfectly normal pupae.

An evaluation of the economic importance of *Sarcophaga aldrichi* will be considered in another paper, but a few records of the abundance of the flies and the percentage of parasitism will be discussed here. The flies were so abundant in many localities that they made field work unpleasant. As can be seen in fig. 4 they seem to be attracted to human skin and would often cluster by the hundreds on the arms, hands and face. In 1938 an attempt was made to get an accurate estimate of the population density of the flies. A portable fly trap was baited with beef for this purpose. As many as 2,146 flies were captured in 2 hours. The trapping record of the seasonal abundance of the species was interrupted by a cool, rainy period after which the population was reduced to a very low level by a fungus disease. Thousands of flies could be seen fastened to the ends of dead twigs, grass heads and other resting places. The

greatest number of flies trapped in any 2-hour period after this decimation was 131.

Cocoon collections were made by state and federal forest rangers for the purpose of determining the intensity of parasitism. The records for 1936 show that *Sarcophaga aldrichi* was present in from 30 to 80 per cent of the cocoons with an average of about 55 per cent. During 1937 the percentage varied between 60 and 100 per cent, and the records from the few areas that were infested in 1938 indicate that from 90 to 100 per cent of the pupating hosts were destroyed by the parasite *S. aldrichi*.

SUMMARY.—Field observations and cocoon examinations have demonstrated that *Sarcophaga aldrichi* attacks *Malacosoma disstria* at the time when the caterpillars are constructing their cocoons and pupating. The life cycle of the parasite is adjusted in such a manner that the flies are ready to larviposit when the first cocoons appear in the field. They produce only one generation a year because of a long period of dormancy after leaving the host. They attack perfectly normal larvae and pupae in their cocoons and are not limited to parasitized or diseased hosts. *S. aldrichi* enters into direct competition with the other parasites and destroys them when they chance to occur in the same host. This species will breed in carrion, mashed caterpillars and other organic material. From the above evidence it may be classed as a facultative parasite which is bridging the ground between a specialized parasite and an exclusive scavenger.—10-27-38.

LITERATURE CITED

Aldrich, J. M. 1915. The economic relations of the Sarcophagidae. JOUR. ECON. ENT. **8**: 242–6.

Caesar, L. 1916. Insects of the season in Ontario. Ent. Soc. Ont. Ann. Rept., **1915**: 32.

Gösswald, K. 1934. Zur Biologie und Ökologie von *Parasetigena segregata* Rond und *Sarcophaga schützei* Kram. nebst Bemerkungen über die forstliche Bedeutung der beiden Arten. Zeit. f. angew. Ent. **21**: 1–23. 6 figs.

Parker, R. P. 1916. Sarcophagidae of New England: Genus Sarcophaga. JOUR. ECON. ENT. **9**: 438–41, 1 fig.

Patterson, T. L. 1911. Investigations into the habits of certain Sarcophagidae. U. S. Dept. Ag. Tech. Ser. **19**: 25–32.

Painting for Determination of Grasshopper Flights

H. R. WILLIS,* *Bozeman, Mont.*

During the summers of 1937 and 1938, efforts were made to determine the migratory habits and directions of flights of the two grasshoppers, *Dissosteira longipennis* (Thos.) and *Melanoplus mexicanus* (Sauss.). The work with *D. longipennis* was carried on in Colorado in 1937 while the work with *M. mexicanus* was carried on in Montana in 1938. The work was done in an effort to determine the direction, distance and time involved in migration, as, if such information were available entomologists might be able to determine the possibility of infestation within a state or possible infestations from an adjacent state and prepare for any such movement. The following is a report of initial trials for flight determinations. More observations should be made in various parts of the grasshopper infested area.

PAINTS USED.—In 1937, experiments were carried on to see what paint would be the best to use in marking the grasshoppers without injuring them or retarding their flight movement. It was necessary to discover a fast drying paint which would not injure the grasshopper and be light in coverage of the painted specimens. A lacquer paint which had additional amyl acetate added at the rate of 4 parts to 1 of paint used was found to be satisfactory for this purpose. The paint that was used most commonly was composed of basic paint pigments, linseed oil and amyl acetate, with enough linseed oil to secure a good mixture of the paint pigments; 4 ounces of amyl acetate were added to each ounce of this mix. Silver and gold paints proved very good colors, the powder being used as a paint pigment and mixed as such.

APPLICATION.—Grasshoppers to be

* Assistant State Entomologist.

painted were caught by sweeping in heavily concentrated areas. A small fly-spray gun was used to apply the paint. After the grasshoppers were caught, usually from 100 to 200 each time, the net was opened to allow them to crawl out, and as they were emerging they were sprayed with the paint. Those that stayed in the bottom of the net were sprayed there and turned out on to the ground to dry. In less than 10 minutes, 90 per cent of the colored specimens had taken wing and very seldom could any dead grasshoppers be found 1 hour after being painted.

grasshoppers are presented in tables 1 and 2.

The distances covered by the grasshoppers of table 1 seemed to be governed by the velocity of the winds and were with one exception in the direction of the prevailing winds of the area in which they were migrating. The distances covered varied from 10 to 37 miles per day. There were two different directions of migrations, those being with the direction of the upper and lower air currents and opposite in direction, but the greater per cent of the grasshoppers sent in were carried by the lower air currents.

Table 1.—Painted and recovered *Dissosteira longipennis* (Thos.) in Colorado, 1937.

PAINTINGS				COLLECTIONS				
Place	Number	Date	Color	Place	Date	Distance	Direction	Number Collected
12 miles south Flagler, Colo.	1,000	7/16	Silver	5 miles north Flagler, Colo. Colo. Spgs., Colo.	7/17 7/29	17 miles 100 miles	N NW	3 3
15.5 miles southwest Kim, Colo.	500	7/22	Gold	No reports				
16 miles north Springfield, Colo.	600	7/13	Green	Pueblo, Colo. Denver, Colo. Clayton, N.M.	7/16 7/26 8/1	115 miles 175 miles 90 miles	NW NW SW	3 1 1
15 miles northeast Eads, Colo.	40	7/10	Methyl red dye	Hugo, Colo. Ariba, Colo.	7/15 7/16	50 miles 60 miles	NW NW	2 1
7 miles north Hugo, Colo.	800	7/15	Yellow	Fort Collins, Colo.	7/20	110 miles	NW	2

PUBLICITY.—After grasshoppers had been painted, efforts were made to have the color and the number painted published in all of the newspapers which were in the possible direction of flight movement; in most cases, because of the novelty of the experiment, the articles appeared in many newspapers, both those in the possible direction of flight and those in other parts of the state.

TIME OF PAINTING.—The painting in both Montana and Colorado was done after some migration had taken place, although in Colorado there had been much less movement than was the case in Montana. Logically the marking of adult hoppers should be done before any movement has taken place if accurate information concerning the whole course of migration is to be secured.

PAINTED AND RECOVERED GRASSHOPPERS.—A record of painted and recovered

These grasshoppers of table 2 were painted after they had migrated into Montana and were moving all of the time, so no accurate information can be obtained from table 2 other than that there was considerable movement within the state and that a great part of this movement was in a northwestern direction, the direction of the prevailing winds; there was, however, a central migration in a southwestern direction.

Migrations averaged 17 miles per day; flights over 50 miles per day were recorded.

When there was no wind blowing, *Melanoplus mexicanus* showed little or no movement in any definite direction but flew into the sky and milled about in large bands, landing in the same area in the late afternoon.

CONCLUSION.—With information on flights as to direction, distance and time

involved, in conjunction with the information which may be obtained from egg and nymphal surveys, entomologists may make preliminary preparations for migrations of *Dissosteira longipennis* and *Melanoplus mexicanus* by having the bait materials on hand, mixing stations ready for mixing bait and preparing the farmers for their baiting campaign. More work of this nature should be done but should be started before any movement of adult grasshoppers occurs from the hatching ground, and a sufficiently large number of hoppers should be painted to insure recovery from the point of origin to the end of the migrations. Colors should be used which will not be confused with normal color patterns of grasshoppers. As large migrations involve more than one state, a marking program should be developed which would eliminate duplication of colors used in various states.

The more publicity that can be obtained by using leased wires of press agencies and working with local newspapers and county agent offices, the greater will be the success of such an experiment. There are definite directions of flights of *Melanoplus mexicanus* and *Dissosteira longipennis*, and these directions, distances and times involved for covering these distances can be determined by painting large numbers of grasshoppers in their hatching grounds and following their migrations through tracing the captured specimens.—11-17-38.

Table 2.—Painted and recovered *Melanoplus mexicanus* (Sauss.) in Montana, 1938.

Paintings				Collections				
Place	Number	Date	Color	Place	Date	Distance	Direction	Number Collected
5 miles east Wibaux, Mont.	3,500	7/24	Yellow	Beach, N.D.	7/25	30 miles	NE	1*
				Fort Peck, Mont.	7/28	130 miles	NW	1
				N.W. Nashua, Mont.	8/1	130 miles	NW	1
				Nina, Mont.	8/1	150 miles	NE	1
				Geneview, Sask.	8/8	230 miles	NW	1
10 miles west Paxton, Mont.	3,000	7/23	Gray	S. Edwards, Mont.	8/3	140 miles	SW	1
14 miles south Willistown, N.D.	2,500	7/19	Gold	Jordan, Mont.	7/25	200 miles	SW	1
				Bonetrail, N.D.	7/22	55 miles	NE	1
				N. Glasgow, Mont.	7/24	190 miles	NW	1
				Chaplin, Sask.	7/28	180 miles	NNW	1
				Kenmare, N.D.	7/26	140 miles	NNE	1
5 miles northwest Wolf Point, Mont.	3,500	7/22	Blue-silver	No reports				
12 miles southwest Sidney, Mont.	5,000	7/19	Silver	N. Glasgow, Mont.	7/27	170 miles	NW	1
				N. Wolf Point, Mont.	7/25	100 miles	NW	1
				Rock Glen, Sask.	8/4	200 miles	NW	1

* One *M. differentialis* found at Beach, N.D., with yellow paint. There were also reported to the office two gold painted *M. mexicanus*, one sent from a bus station at Jamestown, N.D., and the other from a bus station at Blanchard, N.D. It is probable that these were transported by car or bus, and these specimens were not included in the table.

ACCORDING to the Bureau of Entomology and Plant Quarantine, the Japanese beetle quarantine was revised effective February 20, 1939, the principal change consisting of nominal extensions to the regulated areas in Maryland, New York, Pennsylvania, Virginia and West Virginia, and a more extensive increase in the Ohio area. The special area affected by regulations concerning the movement of fruits and vegetables by motor-truck or refrigerator car was also enlarged, and some exemptions were made as to bananas in single bunches and commercially packed peaches.

A New Prophylaxis for Wound Myiasis in Domestic Animals

M. A. Stewart, *University of California, Davis*

The importance of fly-strike in wounds of domestic animals is too well known to require emphasis here. The annual loss from the screwworm in Texas alone (Bishopp 1934) has been estimated at from $4,000,000 to $10,000,000. To this can be added more millions of dollars lost through the attacks of other myiasis-producers. Various substances, tannic acid followed by an application of pine tar or some of the cresol dips (Bishopp, Mitchell & Parman 1922), 1 part furfural and 4 parts pine tar oil (Bishopp, Cook, Parman & Laake 1923), acid free, dehydrated pine tar oil with a specific gravity of 1.065 to 1.085 (Dove & Parman 1935), and bone oil (Howarth 1936), have been recommended for the prevention of wound myiasis in domestic animals and of these the acid free, dehydrated pine tar oil has been the most efficient. However, this material has not been particularly satisfactory in the interior valleys of California and similar places where high temperatures and low atmospheric humidities prevail during the periods of maximum fly activity.

The present investigation was conducted in an attempt to find a more efficient, economical substance which would repel flies from wounds, would stimulate wound repair and would successfully withstand high temperatures and low atmospheric humidities and relatively low temperatures and heavy rains. This last requirement is necessary because in California there is no season of the year when one can be certain that wound myiasis will not occur.

Materials and Technique.—A mixture containing 25 per cent acid free, dehydrated Stockholm pine tar oil with a specific gravity of 1.075, 12.5 per cent amorphous paraffin wax with a U. S. P. melting point of from 160–170 degrees F. and 62.5 per cent viscous oil with the following specifications: flash point Cleveland 540 degrees F. maximum, viscosity at 100 degrees F. Saybolt universal 144,200, viscosity at 210 degrees F. Saybolt universal 2,900–3,200, pour point +50 degrees F. maximum, color A. S. T. M. 2.0 maximum, carbon Conradson 0.5 per cent maximum, sulfur bomb 0.5 per cent maximum and Sligh test 1.0 maximum was used. This compound has a petrolatum melting point of 149.2 degrees F. and a specific gravity at 60 degrees F. of 0.901. A similar mixture but containing 25 per cent pine tar oil, 20 per cent amorphous paraffin wax and 55 per cent viscous oil with a petrolatum melting point of 153.6 degrees F. and a specific gravity of 0.92 at 60 degrees F. was also employed. Another mixture composed of 25 per cent bone oil (100 per cent), 12.5 per cent of the amorphous paraffin wax mentioned above and 62.5 per cent of the viscous oil utilized in the first two mixtures and possessing a petrolatum melting point of 151.8 degrees F. and a specific gravity of 0.886 at 60 degrees F. was tested. A fourth material used in the investigation was straight 100 per cent bone oil.

Two herds of cattle were dehorned with the pincer type of dehorning instrument in September and October, the period of maximum fly activity in central California. Hemorrhage was not stopped nor were any other steps taken, other than the application of the dressings, to decrease the attractiveness of the wounds to the flies. Dehorning wounds were used because they are the most difficult to protect against myiasis, and it was desired to give the above mentioned materials the most rigorous test possible. The first herd, composed of 40 dairy cows averaging about 3½ years of age, was located at Vallejo where the temperature and humidity are influenced by San Francisco Bay. This herd was divided into 4 groups of 10 animals each. One group was treated with the pine tar oil–paraffin–viscous oil mixture, one with the bone oil–paraffin–viscous oil mixture, one with straight bone oil and one was left untreated as a control. These animals were examined daily for 12 days and after that twice more at weekly intervals. The second herd, composed of 38 steers a year and a half old, was located in the northern part of the San Joaquin Valley where the temperatures and saturation deficiencies are much higher. These animals were divided into 3 groups of which 2 groups of 12 steers each were treated with the pine

tar oil–paraffin–viscous oil mixture and the bone oil–paraffin–viscous oil mixture, respectively, and 1 group of 14 animals was left untreated as a control. As the control animals of this herd were struck they were treated and placed in one or the other of the first two groups as the case might be. This herd was dehorned and initially treated on September 30 and examined on October 5, 10, 13 and 18.

The application of both of the viscous oil mixtures was effected by first tamping into each sinus (but not firmly packing) a small piece of oakum, the protruding edges of which were shredded out over the exposed bone to the hair line, thus forming a thatch over which the dressing was smeared with a putty knife and sealed to the surrounding hair; otherwise the dressings slipped off the exposed bone. The bone oil was merely painted over the wounds.

In the analysis of the data each wound was considered separately, since frequently only one wound on the head of an animal is invaded by maggots.

DISCUSSION.—In the experiment conducted at Vallejo the 40 animals were divided into 4 groups of 10 cows each, as described above. Myiasis occurred in 16.67 per cent of the wounds in the group (group I) treated with the pine tar oil–paraffin–viscous oil mixture; in 10 per cent of the wounds in the group (group II) treated with the bone oil–paraffin–viscous oil mixture; in 10 per cent of the wounds of the group (group III) treated with straight bone oil; and in 50 per cent of the wounds in the control group (group IV). The inference could be made from this data that straight bone oil and the bone oil–paraffin–viscous oil mixture are equally efficient in protecting the wounds and more efficient than the pine tar oil–paraffin–viscous oil mixture if it were not for the fact that this latter, which was the 25 per cent pine tar oil, 20 per cent amorphous paraffin wax, 55 per cent viscous oil combination, was so stiff that the same degree and type of coverage of the wounds could not be obtained as with the two other compounds. For the same reason there was less loss of bone oil mixture dressings than pine tar oil mixture dressings, although losses of both were abnormally high because the animals were driven into stanchions for daily examination, and during this operation dressings were knocked off or rubbed off against the stanchions. The pine tar oil mixture, however, showed a greater longevity of protection than the bone oil mixture, since fly-strike where the former material was used occurred on the average 13.5 days later than where the latter was employed. This could be expected when one considers the differences in rate of volatility of pine tar oil and bone oil.

Both types of viscous oil dressings permitted free drainage from the wounds without the dressings themselves being disturbed, but the straight bone oil formed a hard, dry, impervious coating which permitted no drainage at all, which rules out the latter material for use on any wound where drainage must not be inhibited. All of the wounds treated with straight bone oil and all of the control wounds suppurated, while only 16.67 per cent of those in group I and 10 per cent of those in group II were purulent. Eight days after the animals were dehorned 50 per cent of the dressings in groups I, II and III were removed in order that the wound repair progress might be noted. In groups III and IV no granulation tissue had extended out over the denuded bone; in group I excellent granulation tissue extended over the wound in every instance; and in group II fine granulation had occurred, but it was not as extensive as in group I. The oakum packs in the undisturbed dressings were gradually pushed out as the wounds healed over.

The maggots taken from the various wounds were *Lucilia sericata* (Meig.) and *Phormia regina* (Meig.); these two species were about equally abundant. From this experiment it could be concluded that the bone oil–parafin–viscous oil and the pine tar oil–paraffin–viscous oil mixtures were superior to the straight bone oil when applied to dehorning wounds. However, the relative merits of the viscous oil mixtures were not entirely clear.

In the experiment conducted in the San Joaquin Valley the animals were handled as described in the portion of this paper pertaining to Materials and Technique. The pine tar oil–paraffin–viscous oil mixture used in this series of tests was composed of 25 per cent Stockholm pine tar oil, 12.5 per cent amorphous paraffin wax and 62.5 per cent viscous oil, which resulted in a material which could be as easily and efficiently applied as the bone

oil–paraffin–viscous oil mixture. For reasons given above the straight bone oil was eliminated. As indicated earlier, as the control animals were struck they were treated and included in one or the other of the two initially treated groups. Furthermore, as animals in the treated groups developed myiasis they were retreated and returned to the same group. Therefore, there were in this experiment three readings of the two treated groups and the control group and one additional reading of the two treated groups after the control animals had been retired. At the time of the first reading myiasis occurred in none of the wounds of the group (V) treated with the pine tar oil–paraffin–viscous oil mixture, in none of the wounds of the group (VI) treated with the bone oil–paraffin–viscous oil mixture and in 3.57 per cent of the wounds of the control group (VII).

At the second reading there was 4.54 per cent myiasis in group V, 12.5 per cent in group VI and 64.2 per cent in group VII. At the third reading there was 8.33 per cent myiasis in group V, 16.67 per cent in group VI and 44.4 per cent in group VII. At the fourth reading there was 2.08 per cent myiasis in group V and 3.5 per cent in group VI. In group V strike occurred only when the seals had been damaged by rubbing against the corral fence or by knocking against the side of the chute. In group VI three strikes occurred in perfectly intact seals; the remaining strikes occurred in damaged seals. There was 2.7 per cent less loss of seals in group V than in group VI. Again in this experiment the rate of tissue repair was greatest where the pine tar oil mixture was used. As indicated by the above figures, flies were particularly active during the test; *Phormia regina* and *Cochliomyia macellaria F.* were very abundant, *C. americana* C. & P.* was somewhat less abundant and *Lucilia sericata* was still less common, although even this last species was plentiful. It might be stated in passing that *C. americana* larvae were found in wounds under conditions that clearly indicate that it is not necessarily the primary invader it is commonly considered to be.

From this second experiment it is concluded that the pine tar oil–paraffin–viscous oil mixture is a very efficient prophylactic against wound myiasis and is more satisfactory than the bone oil–paraffin–viscous oil mixture. This material possesses a chemical repellent because of the pine tar oil and a mechanical barrier by virtue of the viscous oil which does not inhibit necessary drainage from the wound. Its longevity is not so markedly affected by temperature and humidity as is that of straight pine tar oil and it further aids in preventing myiasis by the stimulation of granulation tissue. With a little practice both dehorning wounds on an animal can be treated in less than a minute.

Observations made during the experiments described above indicate that even when myiasis-producing Diptera are absent, treatment of wounds with the pine tar oil mixture is warranted because of the pronouncedly stimulated wound repair.

Tests conducted before either of the above experiments was initiated upon 100 head of cattle in Kings County demonstrated that the pine tar oil mixture will successfully withstand prolonged heavy rains and low temperatures (30 degrees F.). Similar tests gave equally good results with the temperature going as high as 100 degrees F. and a relative atmospheric humidity of 20 per cent, and there was every indication that much higher temperatures would have no unfavorable effect upon the dressings.

It was found that wounds without sinuses could be easily and quickly dried by applying either motor ether or tannic acid, thereby preventing slipping of the dressing, without a substratum of oakum, off the surface of the wound. In any case the dressing should be sealed to the hair surrounding the wound and the material should be applied generously, which is not an economic handicap since the cost is low. This preferred dressing can be applied to any type of wound susceptible to fly-strike and even better results than those obtained in the above experiments can be expected where an attempt is made during the surgical procedure to render the wound as unattractive as possible to flies, a thing which definitely was not done during the present investigations.

SUMMARY.—A mixture composed of 25 per cent acid free, dehydrated Stockholm

* Some workers consider *Cochliomyia americana* C. & P. to be a synonym of *C. hominovorax* Coq.

pine tar oil with a specific gravity of 1.075, 12.5 per cent amorphous paraffin wax with a U.S.P. melting point of from 160–170 degrees F. and 62.5 per cent viscous oil with the following specifications: flash point Cleveland 540 degrees F. maximum, viscosity at 100 degrees F. Saybolt universal 144,200, viscosity at 210 degrees F. Saybolt universal 2,900–3,200, pour point +50 degrees F. maximum, color A.S.T.M. 2.0 maximum, carbon Conradson 0.5 per cent maximum, sulfur bomb 0.5 per cent maximum and Sligh test 1.0 maximum, applied to wounds, over an oakum substratum when a sinus is present and where a sinus is not present after the wound has been dried by the application of motor ether or tannic acid, affords efficient protection against myiasis and also greatly stimulates tissue repair in the wounds. Its prophylactic efficiency is based upon both a chemical repellent and a mechanical barrier, and wound drainage is not inhibited.—12-5-38.

LITERATURE CITED

Bishopp, F. C. 1934. Screwworm control in the southeastern states. U. S. Dept. Ag. **E-323** (mimeographed circular): 1.

Bishopp, F. C., F. C. Cook, D. C. Parman and E. W. Laake. 1923. Progress report on investigations relating to repellents, attractants and larvicides for the screwworm and other flies. JOUR. ECON. ENT. **16**(2): 223.

Bishopp, F. C., J. D. Mitchell and D. C. Parman. 1922. Screwworms and other maggots affecting animals. U. S. Dept. Ag. Farmers' Bul. **857**: 14.

Dove, W. E., and D. C. Parman. 1935. Screwworms in the southeastern states. JOUR. ECON. ENT. **28**(5): 770.

Howarth, J. A. 1936. The prevention of myiasis in wounds of domestic animals by the use of "bone oil." Jour. Am. Vet. Med. Assoc. 88 n. s. **41**(5): 628–9.

A Contribution to the Knowledge of the Mosquitoes of Owens Valley, Inyo County, Calif.

THOMAS H. G. AITKEN, *University of California, Berkeley*

Not since 1919 has there been any extensive collection of mosquitoes in Owens Valley, Calif. During June of that year Professor William B. Herms, University of California, and his party spent a day going through the Valley making a few collections of mosquitoes as they proceeded southward. Although not extensive, their catch at various places included: Bishop, *Theobaldia inornata* (Will.), *Culex tarsalis* Coq., *Aedes dorsalis* (Meig.); Independence, *A. dorsalis;* Lone Pine, *C. tarsalis, A. dorsalis.* In a region where favorable conditions apparently existed, anophelines were conspicuous by their absence.

A quotation is given from Professor Herm's diary* at this point. "June 23, 1919. Inspected in and around Bishop for about 2 hours and then had a conference with the health officer, Dr. F. E. Turner, who believed that Bishop had had a small epidemic of malaria in recent years. One doctor blamed this on a well and inasmuch as no positive smears were secured, it is very doubtful that it was malaria. Dr. Turner called it a 'bastard' form of malaria, having the right picture but recurring at longer intervals and not responding to usual treatment. Careful search for anophelines was made but none was found. Culicines very abundant and climatic conditions seem to favor presence of former but in fact seem to be absent. There is much water in and about Bishop as is the case with most other smaller communities in this vicinity, due to the nearby snow-capped mountains." It is quite possible that anophelines would have been found if more time had been available.

During the past year the writer was on two occasions in Owens Valley. While he was returning from the Mojave Desert, he made stops at several places on April 17, 1938. At Little Lake (in Rose Valley just to the south of Owens Valley), *Theobaldia inornata* larvae were collected in great numbers amongst the water grass around the border of the lake; many adults were present in the shelter of nearby rocks. At Olancha, larvae and adults of *T. inornata* were taken in a

* Unpublished notes placed at the writer's disposal

marshy area caused by high water in Olancha Creek. At Alabama Hills (about 4 miles north of Lone Pine), principally fourth instar larvae and pupae of the above species were found in side pools of the Owens River; the adults were resting in the nearby grass. All of these collections were made along United States Highway 395. Time was again a limiting factor, preventing additional observations.

The second visit was made a month and a half later, June 1 to 6, 1938. During this period there was greater opportunity to study the Valley's mosquito fauna. It is appropriate to present briefly a few of the topographic and climatic features of the region.

Table 1.—Average monthly and annual precipitation in inches.

PLACE	NUMBER OF YEARS	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
Up to 1937														
Lake Sebrina (9,100 feet)	13	2.60	6.21	1.17	1.23	0.53	0.43	0.80	0.98	0.41	1.09	0.96	4.06	18.09
Bishop Creek (8,390 feet)	29	2.66	3.45	1.09	1.06	0.36	0.59	0.49	0.89	0.18	0.97	0.90	3.44	16.32
Independence (3,957 feet)	52	0.67	0.94	0.15	0.24	0.06	0.02	0.02	0.16	0.19	0.65	0.11	1.23	4.89
Haiwee (3,800 feet)	15	0.51	1.32	0.37	0.42	0.12	0.33	0.11	0.43	0.23	0.38	0.32	1.12	5.65
Up to 1920														
Lone Pine (3,728 feet)	16	1.23	1.03	1.08	0.21	0.41	0.06	0.09	0.16	0.23	0.42	0.11	0.06	5.69
Bishop (4,450 feet)	23	1.77	0.94	0.87	0.22	0.28	0.11	0.11	0.14	0.22	0.20	0.30	0.89	6.05

TOPOGRAPHY.—Owens Valley, 5 to 15 miles in width and situated along the western border of Inyo County, runs in a northwest direction for approximately 90 miles. On the west the Valley is bounded by the towering Sierra Nevada, rising abruptly from the Valley floor; near the southern end of the Valley, Olancha Peak rises 12,135† feet; opposite Lone Pine, Mount Whitney stands 14,501 feet, the highest peak in the United States, and in the northern sector (opposite Bishop) is Mount Humphreys, with an altitude of 13,972 feet. There are 15 or more peaks along this section of the Sierra towering over 13,000 feet. The Valley, itself about 4,000 feet above sea level, is bounded on the east primarily by the Inyo Mountains, rising to 11,127 feet (Waucoba Mountain), by the small Coso Range (Coso Peak, 8,156 feet) in the south (below Owens Lake) and a portion of the White Mountains to the north (White Mountain Peak, 14,242 feet, Mono County). Originally, Owens River, flowing south emptied into the lake of the same name, some 15 miles north of Haiwee (the southern extremity of the Valley); most of its water is now diverted into the Los Angeles Aqueduct, approximately 10 miles north of Independence. The same is true of the many tributary creeks that flow down from the Sierra. The major portion of the Valley is desert, sagebrush, *Artemisia tridentata* Nutt., being extremely prevalent, with creosote, *Larrea tridentata* var *glutinosa* Jepson, appearing much more frequently in the southern portion. However, particularly in the north in the region of Round Valley and in the vicinity of Bishop on the west side of the River, there is an extensive meadowland. Somewhat the same countryside is to be found around Independence and Lone Pine, also to a lesser extent at Big Pine. Lombardy poplar, *Populus nigra* L., and black cottonwood, *Populus trichocarpa* T. & G., are both numerous around these towns.

METEOROLOGICAL CONDITIONS.—The meteorological data for the Valley, based on the records of the various county meteorological stations, is given in tables 1, 2, 3, 4, and 5.‡

NOTES ON THE SPECIES.—During the past 3 years (1936–38), there has been an increased amount of rainfall. The Mu-

† Figures taken from maps of United States Geological Survey.

‡ Climatological data obtained from the U. S. Department of Agriculture, Weather Bureau, San Francisco, Calif.

Table 2.—Average monthly and annual temperatures in degrees F.

PLACE	NUMBER OF YEARS	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
Up to 1937														
Lake Sebrina (9,100 feet)	13	25.7	27.8	32.7	38.0	45.4	54.1	61.1	59.7	52.2	43.4	35.9	28.9	42.1
Bishop Creek (8,390 feet)	28	27.7	29.4	34.5	40.1	47.1	54.3	61.1	59.0	52.8	44.4	37.4	30.6	43.2
Independence (3,957 feet)	40	37.4	42.4	51.6	58.1	65.2	72.9	79.7	77.7	70.4	59.6	48.5	40.2	58.6
Up to 1920														
Lone Pine (3,728 feet)	16	39.9	44.1	49.8	55.9	61.3	69.6	74.8	72.3	65.2	56.5	47.7	39.5	56.4
Bishop (4,450 feet)	20	37.0	41.6	46.2	52.9	59.0	66.9	72.8	71.4	63.9	55.0	45.6	38.0	54.2

Table 3.—Average annual temperature and precipitation record, 1931–37.

PLACE	PRECIPITATION							TEMPERATURE						
	1931	1932	1933	1934	1935	1936	1937	1931	1932	1933	1934	1935	1936	1937
Lake Sebrina (9,100 feet)	22.54	13.91	15.94	11.15	18.76	25.67	21.46	41.5	40.9	41.7	44.3	41.2	42.8	42.3
Bishop Creek (8,390 feet)	18.04	13.47	15.40	11.61	15.93	22.64	16.03	—	42.0	43.5	46.7	42.3	43.1	42.1
Independence (3,957 feet)	6.46	3.24	2.15	3.01	5.49	8.83	5.14	59.5	59.1	57.6	61.2	58.0	58.9	57.1
Haiwee (3,800 feet)	9.95	2.09	—	—	—	6.57	5.46	—	—	—	—	—	—	—

Table 4.—Average relative humidity, per cent, up to 1930, at Independence.

TIME	NUMBER OF YEARS	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
5 A.M.	23	69	66	57	47	46	37	36	40	41	50	57	61	51
Noon	6	34	37	29	26	23	16	15	17	18	22	33	40	26
5 P.M.	23	50	40	28	22	20	16	17	17	20	28	35	45	28

Table 5.—Prevailing wind direction, up to 1930.

PLACE	NUMBER OF YEARS	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
Bishop Creek	14	S	S	S	S	S	S	S	S	S	N	S	S	S
Bishop	25	N	N	S	N	N	NE	S	SW	S	S	S	N	S
Independence	34	NW	NW	NW	NW	NW	NW	SE	SE	NW	NW	NW	NW	NW
Lone Pine	15	S	S	S	S	S	S	S	S	S	S	S	S	S
Haiwee	7	S	S	S	S	S	S	S	S	S	S	N	N	S

nicipal Water Department of Los Angeles, unable to utilize the extra water, has resorted to "spreading" in order to raise the water table which was lowered by pumping during the dry years. This "spreading," which is going on largely near the towns, as well as poor irrigation management is resulting in the creation of vast areas ideal for the breeding of the fresh-water *Aedes dorsalis*. This species was found from one end of the Valley to the other, wherever suitable breeding conditions occurred; it was by far the most prevalent mosquito at the time these observations were being made. Because of the constant annoyance of the female mosquito, collecting was very disagreeable. Apparently the major portion of the mosquito population was on the wing, as relatively few larvae were found. During the previous visit, April 17, no *A. dorsalis* were observed; as collections were not

made at that time in places where this species breeds, no record is available concerning the larval population. The previously-mentioned meadow lands in the vicinity of Bishop, etc., are regularly flooded, some of the water standing for long periods, so that the soil must be figuratively "salted" with eggs. It is this species that causes the townspeople so much annoyance. Although normally a day flier, it readily attacks in the evening.

One place of particular interest as a breeding area may be mentioned. Some 3 miles east of Independence there was an area of burned-over land where water was being spread from Pinyon Creek. A great many *Aedes dorsalis* adults were present, but few larvae were found at first. The soil is very porous (a grey, volcanic ash), and, when the tumble weeds (*Amaranthus graecizans* L.) were burned, had been exposed to the sun and had cracked. The fissures were from 2 to 3 feet deep, with a foot of water standing in them in many places, in which both *A. dorsalis* and *Culex tarsalis* were breeding. This was a bad place, as the cracks had very narrow fissure-like openings or were covered over with new growth, and so in mosquito control work might be easily overlooked.

Another point of particular interest concerning *Aedes dorsalis* was the collection, along with the usual dark forms, of a few females that were conspicuously pale yellow in color. This was at the Thibaut Gun Club (some 5¼ miles northeast of Independence). At first glance the wings appeared to be denuded of scales, but microscopic examination showed the presence of pale straw-colored scales throughout with a very slight general scattering of dark scales. Unfortunately, as no males were seen, the terminalia of the two forms could not be compared. Because of the enormous numbers of adults present, collecting became unbearable. One could speculate as to whether or not we have two varieties here or if the light individuals are merely a color phase. Dyar (1924) described *A. malanimon* from Bakersfield, Calif., separating the new species from *A. dorsalis* by the wing-scales being all dark or at least unicolorous, as well as by terminalia differences. Freeborn (1926) is of the opinion that, if anything, it is merely a race of the latter; hence *A. dorsalis* var. *melanimon* Dyar.

Culex tarsalis, which is undoubtedly the most widespread mosquito in California, was found consistently throughout the Valley. Egg rafts were encountered frequently in fresh, stagnant and alkaline water. This species was particularly active in the evening, annoying people sitting out on their porches. Any doubt that the adults would not suck blood was quickly dispelled when the writer was repeatedly attacked by hungry females, several of which were allowed to engorge to repletion in order to satisfy a curiosity aroused because of statements made that this species does not attack humans (at least in California). *C. tarsalis* was the only species collected around the southern algae-grown margins of Dias Lake, a highly alkaline body of water some 3 miles south of Lone Pine.

The genus *Theobaldia* is represented by two species in the Valley, *Theobaldia inornata* and *T. maccrackenae* (Dyar & Knab), of which the former is the more widespread. Besides the previously mentioned breeding localities (April 17), *T. inornata* larvae (along with *Culex tarsalis*) were found in a small pool of very brackish red water surrounded by rushes, *Typha angustifolia* L.), in Fish Slough, one mile south of the Inyo-Mono County line. The only *inornata* adults taken on the second trip were caught in the evening at Bishop. Whereas on the former visit this species was the only one collected in the Valley, the later date disclosed very few specimens; no evidence of their presence was noted in the breeding areas visited previously. Freeborn states that it is the most prevalent *Theobaldia* south of the Tehachapi Mountains. As far as the writer's collections are concerned, this requires further investigation. During a trip in southern California in the summer of 1937 no *inornata* was found; on the other hand *T. incidens* (Thom.) showed up consistently. However, from the results obtained from the Mojave Desert trip in April, it can be said that *T. inornata* was prominent at that time; in fact it was the only species collected in those arid regions.

Theobaldia maccrackenae was encountered at Lone Pine, in a small dark pool under the roots of an upturned willow tree. Both larvae and adults were collected; the latter were resting on the walls of the dark cave formed by the roots. The

adults had the characteristic swift soaring flight observed by Freeborn. This species, apparently restricted to the Pacific Coast,* is rarely collected in this state. The type locality is Stanford University, Santa Clara County (Dr. McCracken, March, June, 1903). It was taken at Eureka, Humboldt County, June 3 (H. S. Barber), and at the Presidio, San Francisco, July 4, 1906 (C. S. Ludlow) (Howard *et al.*, 1915). Woodworth and Herms collected it at Bakersfield, Kern County, May 27, 1918, and July 28, 1919. Freeborn found it at Vina, Butte County, 1920, and states that "it occurs in the wooded parts of the Central Valley and along the northern coastal section." The writer has also observed *maccrackenae* along the coast at Westport, Mendocino County, August 14, 1937, and Morro Bay, San Luis Obispo County, August 3, 1937. All of the specimens in the writer's possession, from Lone Pine, Bakersfield, Vina, Westport and Morro Bay, have conspicuous pale wing tips, the scales of the apical margin being bronze. Only 2 (males) of 19 specimens have the crossveins in line. The first tarsal segment is not ringed centrally as well as basally as is the case with *T. annulata* (Schrank), a closely allied European species.

Anophelines were found for the first time in Inyo County on June 1, 1938, at Little Lake, thus bearing out Herms' supposition of 1919. This leaves three counties (Alpine,† Mono and Imperial) from which there are no records. Larvae (chiefly third and fourth instars) of *Anopheles pseudopunctipennis* Theob. along with *Culex tarsalis* were collected in the algal patches (*Spirogyra*) at the southern border of the lake. Subsequent rearing records (at Bishop) showed the pupal period to be approximately 30 hours, probably a result of the warm weather.‡

Anopheles maculipennis Meig. larvae (third instar) were collected in a reed (*Typha*) swamp at Bishop, just east of the highway maintenance station; larvae were very scarce; hard work resulted in eight specimens being caught. Subsequent collections indicated that the paucity of anopheline larvae, undoubtedly due to a seasonal factor, was general throughout the Valley. The same species was collected in a roadside ditch 2 miles east of Bishop and in a similar habitat 1 mile southeast of town, also at Independence (4 miles east of town, between the canal and the river near the earthquake fault) in *Spirogyra* clumps around the edge of a small marshy lake, and at the Olevis property, Lone Pine (two blocks west), where a small stream oozed across a grassy field.

The third Californian species, *Anopheles punctipennis* (Say), was also collected at the last two places, as well as in a small willow-shaded creek near the Imhoff tank, which is one mile east of Lone Pine.

The present picture indicates *maculipennis* to be the most widespread of the three anophelines in the Valley, with *pseudopunctipennis* restricted to the southern region. It is quite probable that collections later in the summer would show that all three species are fairly widely distributed.

SUMMARY.—The following seven species are known to be present in or approximately in Owens Valley:—*Anopheles maculipennis* Meig., *A. punctipennis* (Say), *A. pseudopunctipennis* Theob., *Theobaldia inornata* (Will.), *T. maccrackenae* (Dyar & Knab), *Culex tarsalis* Coq. and *Aedes dorsalis* (Meig.).

With regard to malaria a recent conversation with Miss I. M. Stevens, statistician for the California State Department of Health, disclosed the fact that no case has been reported from Inyo County. Miss Steven's records date from 1914. It is quite possible that cases have existed which did not come to a physician's attention or were possibly incorrectly diagnosed. Anophelines are now known to exist in the Valley, but, of course, the size of the mosquito population in the late summer, their proximity to humans as well as their bloodsucking habits, whether anthrophilic or zoophilic, are important points about which little knowledge is available. Furthermore, a carrier must be present to initiate the infection. The sexual phase (Cycle of Ross) of the malaria plasmodium requires for its completion a temperature of 61 degrees F. (16 degrees C.), or above; the optimum temperatures lie between 77 degrees and 86 degrees F.

* *Theobaldia maccrackenae* var. *dugesi* (Dyar & Knab) occurs in the Valley of Mexico and the Western Sierra of Mexico. Ripstein, Consuelo (1932). Anales del Instituto de Biología de México. 3: 249.

† Since the completion of this paper, the writer collected *Anopheles pseudopunctipennis* from an intermittent stream near Lake Alpine, Alpine County, at an approximate elevation of 7,300 feet, September 11, 1938.

‡ Normally, under laboratory conditions at Berkeley the duration of the pupal period is 3 days.

(25 degrees to 30 degrees C.), and above 95 degrees F. (35 degrees C.) conditions again become unfavorable (Boyd 1930). A glance at the temperature record shows there are five months (May-September) during which temperatures are 61 degrees F. or better throughout the greater portion of the Valley. Thus it appears possible for malarial cases to originate in this Valley.—12-22-38.

LITERATURE CITED

Boyd, M. F. 1930. An introduction to malariology. Harvard Univ. Press, Cambridge, Mass., p. 60.
Dyar, H. G. 1924. Two new mosquitoes from California. Insecutor Inscitiae Menstruus, **12**: 125–7.
Freeborn, S. B. 1926. The mosquitoes of California. Tech. Bul. Univ. Calif. **3**(5):333–460, 41 figs.
Howard, L. O., H. G. Dyar and F. Knab. 1915. The mosquitoes of North and Central America and the West Indies. Carnegie Institution of Washington, Washington, D. C. **3**: 494.

The Outbreak of the European Spruce Sawfly in Canada and Some Important Features of Its Bionomics*

R. E. BALCH, *Dominion Entomological Laboratory, Fredericton, N. B., Can.*

In November, 1930, a sawfly was found to have caused noticeable defoliation of spruce over more than 2,000 square miles in the interior of the Gaspé Peninsula in the province of Quebec. When the adults were obtained they were determined as *Diprion polytomum* (Htg). and, tentatively, at least, it was assumed that the species had been introduced.

Since that time the insect has increased in numbers and by the end of 1937 the heavily infested areas totaled some 9,800 square miles of spruce forest in which many trees had been killed. At the same time the insect was known to be distributed widely throughout the forests of northeastern America and was, in general, the most abundant species feeding on spruce in this region.

In view of its importance, the outbreak has been closely studied by the Division of Entomology of the Dominion Department of Agriculture in order to forecast its future development and obtain the information necessary to the program of parasite introduction which was started in 1931. The results of immediate practical importance have been reported on annually (Balch 1938b). The purpose of this paper is to present in a general way certain features of the bionomics of the sawfly which are of interest, particularly in their bearing on the probable future of the outbreak. A discussion of the origin of the insect will also be given, together with a brief outline of the present situation and future probabilities.

* Presented at the meetings of the American Association for the Advancement of Science in Ottawa, Can., June 27, 1938.

LIFE HISTORY.—The European spruce sawfly overwinters in a cocoon spun just beneath the surface of the ground, in moss, litter or humus; it practically never enters the mineral soil. It is generally in the eonymphal stage but sometimes overwinters as a pronymph.

In the spring, development commences in a varying percentage of the cocoons shortly after the snow has melted. Pupation takes place and most of the adults emerge during a period of 2 or 3 weeks, although there are always many stragglers and in some seasons emergence is irregular and may be spread over the greater part of the summer.

Reproduction is parthenogenetic. The eggs are laid singly in the needles of spruce trees, a preference being shown for the older needles which are spaced more widely owing to the increase in size of the branchlets. They hatch in approximately 10 days and the small green larvae eat pieces out of the needles, avoiding the new growth. Later, they consume the whole needle from the tip, most of the feeding being done in the fifth stage.

After they moult to the sixth stage, no feeding takes place, and shortly each larva drops to the ground to spin its cocoon, generally beneath the tree on which it has been feeding.

NUMBER OF GENERATIONS.—In the Gaspé region one generation is the rule. South of the Gaspé, where the season is longer, a small second generation occasionally appears and in central and southern New Brunswick two generations occur normally. Further south there is evidence

that three generations may occur but we have no proof that they are a normal occurrence in the forest anywhere in Canada.

Although in years of cool weather and delayed emergence there is sometimes a considerable loss of larvae which have developed too late and too slowly to spin cocoons before permanent frost, experiments have shown that the insect is capable of adjusting itself fairly well to the length of season, and the great majority remain in diapause when the season is too short to permit another generation to be successfully completed. Some adults do emerge, however, too late in the season to allow their offspring to mature.

DIAPAUSE.—The percentage of overwintering larvae which develop into adults varies considerably from season to season and place to place. It is consistently smaller in the more northerly districts and apparently increases with the length of the season toward the south. In the Gaspé it has averaged close to 20 per cent, in central New Brunswick around 70 per cent and in southern New England it would appear to be considerably higher. It may vary widely, however, in one locality from year to year. The lowest percentage which we have measured by careful field studies was 2 per cent in Kamouraska County, P. Q., in 1934, while at the same point in the following 3 years it has ranged from 12 to 28 per cent. Such annual differences have always been reflected in the size of the population of feeding larvae and are responsible to a considerable extent for annual fluctuations in the amount of foliage destroyed.

Controlled experiments, still in progress, have shown that temperature has a significant influence on the tendency to go into diapause, and both temperature and humidity are of prime importance in breaking diapause. There is, however, a varying inherent tendency toward diapause which appears to be genetic. A number of pure lines have been reared from single females under identical controlled conditions in the laboratory. Some have produced emergence without diapause in each generation as long as they have been reared, although occasional individuals have gone into diapause. One such line was continued without stop for 21 generations. Others have produced a higher percentage of diapause which eventually reached 100 per cent. Lines from females taken in the Gaspé have all shown a particularly high tendency towards diapause and none has developed beyond the first or second generation, except in the case of one female which emerged to produce a third.

In two-generation areas lines with a smaller tendency to diapause would have a greater advantage in reproduction than in one-generation areas, and this may explain the lesser amount of diapause toward the south. Diapause also appears to be associated with later or slower development.

Exposure for a certain length of time to temperatures below the threshold of development is generally necessary to break diapause. About 3 months of this "cold rest" appears to be needed to bring about the maximum amount of emergence from a lot of dormant cocoons, but many do not begin to develop until they have experienced two or more such periods. Emergence has taken place from cocoons which have remained for 6 years in diapause in the forest.

It has been found that the degree of humidity has a controlling influence on the percentage emergence from diapause, although maximum emergence is obtained only after contact with free water. Experiments now being carried out by M. L. Prebble indicate that soaking of the cocoons greatly increases the percentage of adult emergence. Our knowledge of the factors influencing diapause is not, however, sufficient as yet to explain satisfactorily the annual variations in the field. It seems probable that moist conditions and a warm spring favor a high percentage of emergence, although this is limited by the inherent tendency in the population as determined by inherited characteristics and ecological history.

REPRODUCTION.—The insect in Canada is thelytokous. Males are rare and occur in the field in the proportion of about one to every 1,200 females (47 out of 55,680 recorded emergences). They appear occasionally among families of females from an unmated parent. The tendency to production of males is much greater in some lines than in others. In one, as many as 95 have been reared to 3,361 females, or 1:37.

Mating is rare and the instinct appears

rudimentary. Only two cases of attempted mating have been observed and in both cases the offspring were all females. There is no doubt that reproduction is entirely parthenogenetic on this continent. No significant differences in the proportion of males have occurred in different years or in different parts of the infested region.

FLIGHT.—On emergence the adults are somewhat sluggish. However, in fairly calm weather, and particularly when exposed to direct sunlight, they soon take to flight. They fly strongly, and their direction is determined by air currents.

A considerable amount of evidence has been obtained to show that the sawfly has an instinct for flight which is, temporarily at least, independent of the proximity of spruce. Large numbers have been observed on the tops of mountains above timber line and a great many adults drop into lakes and rivers. Although the longest distance from the nearest spruce at which adults have been taken from water is 1 mile, the probability is that many of these came much longer distances. When liberated, such adults again take to the air, flying strongly as soon as they are dried out. Studies of the ovaries of these insects show that nearly all have laid some eggs prior to flight but most of them are capable of laying the greater part of their normal complement of eggs after having taken flight.

Prior to the appearance of heavy infestations in a region it has been found that a fairly general distribution of the insect has taken place. The first sign of trouble is the occurrence of noticeable defoliation here and there over small scattered areas, sometimes less than 100 acres in extent. This has generally been followed by an expansion of these areas and a greater uniformity of attack developing over the region so that the heavy infestations tend to coalesce, subject of course to local differences in type of forest and other limiting conditions. It is especially noticeable that when a large percentage of the old foliage of the trees on one of these first areas of defoliation has been destroyed the number of larvae at this point does not increase in the same proportion as in surrounding, less heavily defoliated, areas. This condition seems to be dependent on the adults' being fairly active in flight during the period of oviposition. Experiments indicate that such flight is encouraged by clear, calm weather.

Since the adults fly strongly, and sometimes at a considerable altitude, they must often travel many miles with the assistance of air currents. The thelytokous habit of reproduction permits establishment of the insect from a single individual provided it reaches a stand containing spruce.

FEEDING HABITS.—The larvae feed only on spruce (*Picea* spp.). They cannot eat the needles of the current year's growth until it is fully grown and this new foliage does not generally become completely palatable to them until the following year. In the case of red and black spruce, *Picea rubra* and *P. mariana*, very little feeding takes place on the current year's growth and this is mostly on trees which have lost all their old foliage. In the case of white spruce, *P. glauca*, a considerable amount of feeding may take place on the new needles in the latter part of the summer in two-generation areas, particularly after the old foliage has become scarce. Needles a year or more old are preferred, however, at all times, although there is considerable variation between individual larvae. Some may be found feeding by choice on new foliage as soon as it is fully formed. We have reared families in the second generation from egg to cocoon on new foliage of white spruce, but this rearing is not possible on red and black spruce.

Some preference is also shown for the white spruce in oviposition although this is not very marked. At the same time experiments have indicated that larvae reared on white spruce are somewhat larger and have a greater egg capacity as adults than larvae reared in the other two spruces. The white spruce, therefore, is both more favorable to the sawfly and more easily killed than red or black spruce. Large pure stands of both the latter species have been severely attacked, however, and have suffered mortality. Although little of the new foliage is consumed the branches gradually die. Almost complete defoliation followed by death of the tree eventually results.

Norway spruce, *Picea excelsa*, blue spruce, *P. pungens*, and Sitka spruce, *P. sitchensis*, are also attacked.

EVIDENCE OF EUROPEAN ORIGIN.—When the outbreak was discovered in

1930 there was no previous record of the occurrence of *Diprion polytomum* in America. Specimens have since been identified, however, which were taken near Ottawa, Ont., in 1922, and on Mount Washington, N.H., in 1929. These records indicate that the species had been widely distributed for some years before the outbreak was found.

During the past few years surveys by entomologists, forest services and operating companies in Canada and the United States, and particularly the forest insect survey of the Dominion Division of Entomology, which has handled many thousands of samples beaten from spruce throughout Canada, have given what would seem to be an accurate picture of the distribution. The indications are that the sawfly does not occur west of longitude 81 degrees.

Studies of tree growth and cocoon population show that the sawfly was very numerous throughout the interior of the Gaspé Peninsula by 1928 and has been present in Canada probably since before the beginning of the present century. Whether it was introduced from Europe, and, if so, at what point, cannot be definitely determined. If we bear in mind, however, the method of reproduction and the powers of flight, the foregoing records are not incompatible with the theory of introduction. If the species were native, it would probably have been found throughout the spruce forests which extend from Ontario north of the prairies to British Columbia.

The fact that the insect has more or less persistently increased in numbers ever since it was discovered and that the heavily infested area has continued to spread, involving all types of spruce forest, suggests that this sawfly is not native to North America and has not yet occupied its possible range. Our studies indicate that it is adapted to conditions obtaining throughout most of the spruce forests in North America.

Perhaps of chief importance is the virtual absence of attack by native parasites. Some 276,000 cocoons and mature larvae, collected from widely separated points throughout the whole of the known range of the sawfly during the past 7 years, have been carefully reared. Of these, only 54, or less than 0.02 per cent, were successfully parasitized by native species. Almost half of these produced *Bessa selecta* Meig., a common parasite of *Pristiphora erichsoni* Htg. and possibly of European origin itself. The remainder were attacked by 17 different species. It seems improbable that an indigenous sawfly could be almost free from parasite attack while related species of *Pikonema* and *Neodiprion* on the same trees are often quite heavily parasitized.

The fact that the genus *Diprion* is confined to Europe, except for the species *nipponica* which occurs in Asia and *simile, frutetorum* and *sertifer*, all of which have apparently been recently introduced to America, would seem to increase somewhat the probability that *polytomum* is not native to this continent, although it might of course be circumpolar in distribution. Since the Canadian form is thelytokous, however, and this type of reproduction probably developed from a bisexual type, its most likely origin would be in a region where a closely related bisexual form occurs; no such form is known in Canada.

COMPARISON OF CANADIAN AND EUROPEAN FORMS.—As our studies progressed it became evident that, although no distinct morphological differences had been found to separate the Canadian adults from *polytomum* as known and described in Europe, there were some rather important biological differences.

The seasonal history appeared to be essentially the same, with similar variations in number of generations from one in the Riesengebirge Mountains and more northerly parts, such as Sweden, to two in most of Czechoslovakia and three in Hungary. There was a difference, however, in the location of the cocoon. Throughout central Europe, according to Dr. Kenneth Morris, the great majority of the first generation were spun in the spruce foliage and those of the second generation were spun almost entirely above ground, although they tended to go to the lower branches or to the herbaceous growth beneath the trees. At higher elevations, however, some cocoons were spun on the ground. In Canada, all cocoons are spun in the ground—with occasional exceptions. As we have found that exposure to temperatures below −1 degree F. causes some mortality and all hibernating larvae are killed at −22 degrees F., this is an essential adaptation

in Canada where winter temperatures generally go below −22 degrees F.

Another difference of a similar order lay in the tendency to go into diapause. While this habit was noted by Dr. Morris in Central Europe, it was apparently limited to less than 5 per cent of the population. Possibly, however, further study might demonstrate that diapause is a more common phenomenon, particularly in northern Europe.

The most important biological difference between the Canadian and the European forms appeared to lie in the method of reproduction. In Europe, judging from a considerable number of collections made in Czechoslovakia by the Farnham House Laboratory and reared by the Dominion Parasite Laboratory, the males are approximately as numerous as females, although the ratio varies in different collections and females seem more often to exceed the males in number. We have no information on the results of mating but unmated females whose progeny were reared by Dr. Morris produced only males. Evidently the form studied in Europe was arrhenotokous.

It became necessary to determine the importance of these differences. As parallel comparative rearing experiments were not possible, a cytological comparison suggested itself. It was thought that this would explain the method of sex determination and at the same time throw some light on the question as to whether the Canadian and European forms were distinct.

A study of the chromosomes was therefore commenced by S. G. Smith in 1936. He found that both the thelytokous Canadian material and the arrhenotokous European material had the haplo-diploid type of sex determination. The first maturation division in the oocyte was apparently reductional in both cases but the process by which the diploid number was retained in the Canadian female was not determined, although it was considered probable that auto-fertilization took place by a fusion of the second polar body and the female pronucleus. The occasional male in this case would result from a failure of this process. This work is being continued (Smith 1938).

An important difference was found, however, in the number of chromosomes. In all the Canadian material the haploid number was seven; in the European material six. Thus, a distinct cytological difference was demonstrated between two forms, the separation of which on morphological grounds had proved difficult.

TWO FORMS IN EUROPE.—This confirmed our opinion that two distinct forms were involved and emphasized the importance of trying to determine the origin of the Canadian form. If, as the evidence suggested, it came from Europe, the difference must have been acquired after introduction or else the two forms already existed in Europe and only one had hitherto been recognized.

That the latter is the case has now been fairly well established by Dr. Smith's discovery in 1937 that females with 14 chromosomes and also females with the thelytokous type of reproduction occur in Europe.

Also, W. A. Reeks (1937) has found that there are two morphological forms in the European material which he has studied. These are most easily separable on the basis of characters in the genitalia. One of the forms resembles the Canadian type, but it is not known yet what correlation there is between the morphological and physiological characters in Europe. It is hoped that it will be possible to determine this by a study of the biology and morphology of reared families.

The evidence to date indicates that we are dealing in Canada with one of two European forms of *Diprion polytomum* which was probably introduced during the nineteenth century.

PRESENT DISTRIBUTION.—The sawfly is now known to be present in all spruce stands in New Brunswick and in Quebec south of the St. Lawrence River. It has been taken in small numbers at scattered points in Nova Scotia and Prince Edward Island. It is apparently well distributed throughout all the New England states and New York state wherever spruce occurs. In Quebec, north of the St. Lawrence, it has been found in most places from the Moisie River west. In Ontario it has been taken fairly generally east of longitude 81 degrees. In spite of the activities of the Forest Insect Survey, however, it has not been taken in western Ontario or any of the western provinces. The known area of distribution covers some 145,000 square miles, of which some 25,000 are in the United States.

DEGREE OF INFESTATION.—A method of classifying infestations as "light," "medium" or "heavy" has been adopted for survey purposes (Balch 1938a). The "heavy" infestations are characterized by a loss of from 25 to 100 per cent of the foliage and may be said to have a population of 10 or more sound cocoons per square foot beneath the trees. They are considered to have reached the stage where a progressive increase in defoliation is probable and can take place without any further increase in sawfly population.

In 1937, 9,800 square miles were estimated as heavily infested. Practically all of this area was in the provinces of Quebec and New Brunswick south of the St. Lawrence River although areas occurred in southern New Hampshire and Vermont and northern Maine.

"Medium" infestations occurred over an approximately equal area in much the same regions. These are characterized by slight defoliation, visible only on close inspection and a population of about two to nine sound cocoons per square foot under the trees. The remainder of the area of distribution, including all that north and west of the St. Lawrence was only lightly infested.

DAMAGE.—To date, the damage, which consists of mortality and loss of growth and vigor, is confined to the heavily infested areas. Actual dying of trees has occurred as yet only in the region of the Gaspé Peninsula except for scattered stands west of the Matapedia and in New Brunswick, where a few trees have begun to die.

The mortality has already become high in the interior of the Gaspé Peninsula. This was hastened by an outbreak of *Dendroctonus piceaperda* Hopk. which occurred between 1931 and 1934. For the past 6 years, the upper waters of the Ste. Anne and Cascapedia rivers, which are typical of this region, have been cruised annually by M. L. Prebble. The white spruce began to die first, followed a year or two later by the black spruce. In the fall of 1937, 65 per cent of the volume of the white spruce, including 44 per cent attacked by *Dendroctonus*, and 27 per cent of the black spruce, was dead in the white spruce type. This is the most easily accessible and valuable type of the Gaspé forest. On the steeper black spruce slopes and in pure black spruce flats the mortality ranged from 5 to 40 per cent. The condition of the remainder of the trees is such that many of them would be incapable of recovery even if the sawfly attack ceased.

Considerable, but less severe mortality, was appearing outside this central Gaspé region, particularly in young stands, although all age classes and types were heavily attacked. West of the Matapedia and in New Brunswick, however, the trees, with a few exceptions, were still capable of recovery if not injured further. Many stands, however, had lost over half their foliage and showed a large reduction in growth.

FUTURE DEVELOPMENT OF OUTBREAK.—The sawfly is well adapted to conditions in the Canadian spruce forests as far as feeding and climatic conditions are concerned. Its host plants form a large proportion of the stand over immense and unbroken areas. In the egg and feeding stages it can endure the highest and lowest temperatures it is likely to experience. No serious mortality has resulted from air temperatures as high as 100 degrees F. or as low as 22 degrees F. and some feeding larvae have survived 13 degrees F. In the hibernating stage the low lethal temperature ranges from 0 degrees F. to −22 degrees F. but the habit of spinning up in the ground gives almost complete protection from such temperatures, even in the absence of snow.

The larvae thrive in moderate to high humidities such as generally obtain in our forests and do not suffer much from heavy rains, except for a short period after hatching. In the cocoon stage they can survive complete immersion in water for several weeks or being frozen in ice during the winter. Very wet, undrained conditions in spring and summer cause mortality but the moss and litter in which most of the cocoons are spun is generally moist but well drained.

No natural enemies have yet appeared which seem likely to prevent increase in numbers up to the point where serious defoliation occurs. Mice, shrews and squirrels are the most important but they have apparently never taken more than half the cocoons (Balch 1938a). Insect predators, chiefly *Podisus serieventris* and Elaterids, are generally distributed but

are limited in effectiveness, and native parasites have been shown to be completely ineffective. Birds are not sufficiently numerous in spruce forests to destroy an important percentage.

Two kinds of disease have appeared on the sawfly: one a type of "wilt," the other caused by a fungus. Neither of these, however, has been very common in the forest although they have occasionally caused considerable mortality under laboratory conditions.

We have, therefore, an outbreak of a species which has most probably been introduced from Europe into an environment at least as favorable as that from which it came, and which lacks effective natural enemies. At the same time it has a very efficient method of reproduction which doubles the rate of increase as measured by the egg capacity of the female in comparison with strictly bisexual species, makes it independent of the necessity of mating and permits it to develop more rapidly in newly invaded areas. It also has a habit of remaining in diapause, which tends to protect it from catastrophic reductions in numbers.

There is considerable evidence that parasites are of prime importance in determining the density of insect populations and their fluctuations. Recently, Nicholson (1933) has demonstrated theoretically that the essential factors tending toward the balance of populations are those which are themselves governed by the density of the population controlled and that these come under the heading of competition, either for the necessities of existence or between natural enemies. In general, predators do not seem to be able to increase as rapidly as parasites with the increasing density of the host, and in the absence of parasites the sawfly seems to lack the factor of control which would be most likely to reduce its numbers before the trees become seriously defoliated and competition for food begins to exert its effect.

Control by starvation becomes important about the time that some 90 per cent of the "old" foliage has been eaten and the larvae are forced to eat a considerable amount of new foliage. At this point the population of cocoons begins to decrease. The trees do not die until all the old and over half of the new foliage is destroyed. The cocoon population, however, tends to maintain a sufficiently high level to continue to destroy the old foliage and part, at least, of the new. Meanwhile, weakened branches die until there is insufficient foliage to maintain the life of the tree. This process, leading up to complete defoliation, is often rather gradual and may occupy anywhere from 2 to 10 years from the time of first noticeable injury.

Judging, therefore, from the behavior of the insect to date and the knowledge we have been able to obtain regarding its ecology, it seems probable that the areas of heavy infestation will continue to increase and that new ones will appear which will tend to enlarge and coalesce. At the same time it may be pointed out that the insect's reluctance to eat new foliage generally prevents the rapid killing of trees and a comparatively moderate addition to the natural factors of control may be sufficient to prevent their actual destruction. This is one of the chief reasons for hope that the introduction of one or more effective parasites will eventually produce economic control of the outbreak. Although it is important to prevent reduction in growth, the immediate economic problem is to preserve the life of the trees. Perhaps the insect will eventually be reduced to the status of a native insect, with or without periodic outbreaks. The object is to hasten this process and, if possible, to keep the population level below that at which serious defoliation takes place. Although other environmental factors may do this, it seems probable that they will not be permanently effective without the assistance of parasites, either through the adaptation of native species or more probably through the introduction of new species. —12-30-38.

LITERATURE CITED

Balch, R. E. 1938a. Estimation of spruce sawfly hazard and need of salvage. Pub. by Pulp & Paper Association of Canada and Ent. Br., Dom. Dept. of Ag., Ottawa.

Balch, R. E. 1938b. The spruce sawfly outbreak in 1937. Pulp & Paper Mag. of Canada, March.

Nicholson, A. J. 1933. Balance of animal populations. Jour. of Animal Ecology. **2**(1): 132–78.

Reeks, W. A. 1937. Morphology of the adult of *Diprion polytomum* (Htg.). Can. Ent. **69**(12): 257–64.

Smith, S. G. 1938. Cytology of spruce sawfly and its control in eastern Canada. Nature, **141**: 121

Psocids in Dwellings*

E. A. Back, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Psocids are insects which entomologists have dismissed as being of little economic importance as household pests.† Psocids do not bite persons. No one suspects them of carrying disease. They are not destructive to growing crops. They do not seem destructive to stored agricultural commodities. During the past 20 years no instance of injury by psocids to any stored product, or to any house furnishing, has come directly to the attention of the writer, and he has visited many warehouses in all parts of the country and observed the destructive work of storage pests.

The Review of Applied Entomology, which covers the entomological literature of all countries, has listed during the past 25 years not more than an average of one reference a year to psocids, and most of these references merely mention psocids as present in certain supplies or on certain crops. Since its organization in 1921 the Insect Pest Survey, operated by the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, has acquired only 131 references to psocids, taken mostly from monthly reports of state and federal entomologists. In spite of this dearth of real information concerning psocids, the correspondence of the Bureau has increased during each of the years 1937 and 1938 fivefold over that received during 1936. The interest in psocid control, so far as this Bureau is concerned, is greater today than at any time during the past 20 years.

Information Generalized, the Result of Casual Observation and Correspondence.—If it is true that house-infesting psocids may be dismissed by the entomologist as pests not harmful to the products of agriculture and industry, and as incapable of biting man or carrying diseases, why are they suddenly demanding so much attention? Entomologists know that psocids are commonly found out of doors, and often indoors; that their activity and increase are associated with warm dampness caused by one thing or another, but particularly by long spells of humid weather; that cold winter weather and the dryness of buildings due to furnace heat seem to cause them to disappear; and that they often become most abundant late in the summer and early in the fall. But most of this generalized information, which seems dependable, is the result of casual observation and correspondence and not the result of careful study, except perhaps in a very few isolated cases.

Psocids the Cause of Heavy Losses to Property Owners.—The unusual interest of today is due to heavy losses sustained by property owners resulting, not from the destruction of buildings and furnishings, but from broken leases, lawsuits to recover damages for fancied loss to health and furnishings, and the payment of fees for the services of pest control operators, as well as to the desire of pest control operators for information on the biology and control of psocids. Housing commissioners have gone so far even as to issue orders for the closing of psocid-infested apartment houses, which, if actually put into effect, would have entailed terrific loss. Some apartment owners have refused to rent to tenants moving from infested buildings for fear of introducing "lice and vermin" into their own buildings. Fear based on ignorance, the erroneous association of psocids with true lice and disease, the mental uneasiness of the uninformed and the use made of psocids by unscrupulous persons to refuse the payment of rents and to force cash settlements through the instigation of lawsuits have been the greatest factors in arousing public interest in psocids.

Psocids Alarmingly Abundant in Newly Constructed Modern Buildings.—A general review of correspondence and literature indicates that, while psocids are apt to be present in alarming numbers in all sorts of buildings, the great difficulty centers in newly constructed metropolitan apartment houses. As a rule, the infestations develop in four months to one year after the building has been opened for occupancy, depend-

* Early publication of this paper has been secured by payment of the printing charge.

† There are many species of psocids, but those responsible for house infestations usually are *Liposcelis divinatorius* (Müll.) and *Trogium pulsatorium* (L.). In the literature one often finds *Troctes* for *Liposcelis*, *Liposcelis* and *Atropos* for *Trogium*. Specific determinations were made by A. B. Gurney.

ing upon the season of the year completion occurs. The building of fireproof apartment houses today incorporates large amounts of moisture in the walls and floors during construction. The buildings are hurried to completion because of the great investment involved, and no thorough drying-out can take place prior to occupancy. Hollow tile and similar materials, and insulation, slow down evaporation of moisture from wall spaces and from between floorings. The escape of moisture is retarded also by the finishing mortars, wooden trim, layers of paint, wallpaper and paste.

Psocids can usually be found on most building materials before they are incorporated into the building. They are as likely to be found crawling on metal materials and composition boards as upon wood, and particularly in the vegetable wrappings of plumbing and electrical fixtures. Microscopic molds abound on most building material that has been exposed to much dampness. The sealed-in moisture and ultimate warmth induce psocid increase. In badly infested building psocids are abundant, not only on the outer surfaces of room walls and trim, in cupboards and in other places where they can be seen, but in spaces between floors, in walls, behind the door and window trim, and behind electrical and other fixtures. This indication of development of infestations from within in new buildings has been evidenced by examinations made when trim and fixtures have been removed.

While building materials can account for the presence of psocids in newly occupied apartment and other buildings, there are many other sources for which the tenant is responsible. Infestations are not necessarily the fault of the builder or owner. New upholstered furniture containing tow and Spanish moss, rugs, books, papers, groceries, cartons of merchandise, straw matting, contents of trunks taken from storage etc. may carry psocids. Psocids may come into buildings even on the daily newspaper and on cut flowers.

FOOD OF PSOCIDS NOT WELL UNDERSTOOD.—The food of psocids within houses has not been studied. Much of the injury to papers, book covers, wallpaper etc. generally attributed to psocids should have been charged to silverfish and cockroaches. The writer has known of no person corresponding with the Bureau of Entomology and Plant Quarantine who claimed that psocids, no matter how abundant, were causing injury, while many correspondents have stated definitely that they could detect no evidence of injury. It is true that a few authors ascribe definite capacity for injury to certain of our cosmopolitan psocids, particularly *Liposcelis divinatorius* (Müll.) and *Trogium pulsatorium* (L.). But are these claims based upon studies of isolated cultures or are they restated older generalized claims? Until data have been obtained and definitely recorded it seems best to consider that psocids in the United States do not damage house furnishings, wearing apparel, rugs, wallpaper etc. but subsist mostly upon microscopic molds prevalent upon building materials, house furnishings, wallpaper, etc. These molds are present in abundance in many damp situations where they would not naturally be expected. It is recorded definitely that *L. divinatorius* devours the eggs of the Angoumois grain moth. It is claimed that psocids feed also upon carbohydrates. Today, when there is such competition among various types of building materials and other aids to home beautification, one should guard against unproved statements which might predjudice builders against the use of certain classes of materials. In most instances, the drying out of buildings and furnishings which stops mold growth also stops psocid abundance. The writer is not entirely satisfied, however, that molds are prime food of psocids in buildings, and realizes that he opens himself to the criticism of making an unproved statement. But he is aware of the controversies stirred by the presence of psocids and feels that until there has been some careful investigational work on this subject, less injustice is done by considering that microscopic molds are their chief food in dwellings.

NO EXTENSIVE STUDIES OF PSOCID BIOLOGY EVER MADE.—Until 1930 nothing of value appears to have been published concerning the biology of psocids likely to infest buildings. During that year O. W. Rosewall (1930) of Louisiana State University, published the results of his studies of *Liposcelis divinatorius* (determined by A. N. Caudell). He found no

males and that parthenogenesis always occurred. His data indicate that from October to January, when the temperature was 50 degrees to 87 degrees F., the preoviposition period ranged from 31 to 54 days (average 45 days), the egg laying capacity was from 7 to 44 eggs (average 20 eggs), and the egg stage from 11 to 27 days (average 21 days), and that the life cycle ranged from 111 to 130 days and the postoviposition period from 1 to 24 days (average 9 days). For the period June–August, when the temperature was 60 degrees to 95 degrees F., the average length of the egg stage was 6.9 days, the average egg laying capacity 57 eggs and the average life cycle 24.4 days. Rosewall found one female that lived from June 27 to October 27 and deposited a total of 98 eggs.

L. R. Findlayson (1932) in Ontario, Canada, stated that at 80 degrees F., with a relative humidity of 65 per cent, *Liposcelis divinatorius* required about 1 month to pass through the developmental period, and that after a preoviposition period of 2 to 3 weeks eggs were laid at the rate of one every 12 hours until 75 per cent of the total egg laying capacity was reached, after which eggs were deposited at longer intervals.

G. S. Candura (1932), in southern Italy, wrote that *Liposcelis divinatorius* required 21 days in summer to 140 days in winter to pass through the developmental period, that females laid an average of 50 to 60 eggs in summer and 20 in winter, that the egg stage requires 4 days to 4 weeks, that adults live 1 week to 3 months, that all stages occur in winter, that there may be six to eight generations a year and that reproduction is always parthenogenetic.

CONTROL MEASURES.—Control measures for psocids are very briefly discussed in entomological literature. They include applications of dry heat (120–140 degrees F.), and sunshine, dry storage and fumigation with hydrocyanic acid gas and other common fumigants, including sulfur dioxide generated by burning 25 to 30 ounces of sulfur for each 1,000 cubic feet of space. Naphthalene, paradichlorobenzene, sodium fluosilicate, derris and pyrethrum dusts, and contact sprays are also recommended. General experience of pest control operators and others seems to indicate that no one application or combination of controls is likely to give results under all conditions, for no matter how thorough the application, unless all concealed spaces in walls and flooring and behind trim and fixtures are reached by the fumigant or spray, reinfestation is likely to occur very soon. Perseverance in applying control measures seems to be necessary to bring stubborn apartment house infestations to an end.

NOTES FROM CORRESPONDENCE.—The following notes are from correspondence relating to psocids.

Baltimore, Md., December, 1934.—Dependable fumigator failed to eliminate psocids in house by fumigating house with 8 ounces of hydrocyanic acid discoids per 1,000 cubic feet. Refumigated with 20-ounce dosage and after ventilation found house well infested with living psocids. This condition indicates reinfestation from usual sources.

California, February, 1935.—Psocids in piano, sideboard, suitcases etc. Back of bureau covered with them. No matter how much I spray they still crawl out; 40 minutes after spraying with kerosene living psocids are found crawling over sprayed area.

Pennsylvania, June, 1935.—First noticed psocids near windows, on window panes, especially on cellar windows. Traced psocids to lawn, where they were abundant in grass.

Virginia, June, 1935.—Psocids present on woodwork and furniture. Have sprayed well with oil-pyrethrum spray, but it is expensive and in a day or so the psocids appear again.

West Virginia, August, 1935.—Psocids present in flax tow shipped in 100-pound bales from Minnesota. Stock received damp in April but stored in dry, well-aired space. Bales heavily infested by August.

Minnesota, September, 1935.—Fumigated with chloropicrin, triple strength, when psocids were swarming about window sills. A week later psocids reappeared and were found abundant in empty canvas-lined trunks. Sunning articles does not help to eliminate house infestation.

Missouri, November, 1935.—Have fought psocids with sulfur candles and hydrocyanic acid gas with no lasting results. A spray with an oil base was more effective, and we are now rid of insects.

California, May, 1937.—Used various

sprays and sodium fluoride. Next year fumigated with hydrocyanic acid gas, but continue to find psocids, especially on window sills.

Idaho, July 1937.—Two hydrocyanic acid gas fumigations failed to eliminate psocids from house.

Ohio, August, 1937.—In the spring the house was flooded 2½ feet above the second floor. During the past month psocids have been increasing. Most abundant on newly papered walls but some found elsewhere.

New York City, August, 1937.—Have been troubled recently with psocids. They are in all newly constructed buildings in the Bronx. Old buildings are all right. Each apartment of our six-story apartment house is infested. The insects are on the walls, window sills, books, furniture and clothing. Everything is overrun with them. Tenants are moving out. The Health Department has been appealed to. The outer walls of the building are also infested, as insects continue to come into the building. Have used sulfur, paradichlorobenzene, pyrethrum sprays, etc.

Brooklyn, N. Y., August, 1937.—The house, completed and occupied 4 months ago, is infested with psocids and springtails. They are crawling from behind baseboards, chair rails and cove moldings, and from small cracks in plaster. They are in every room but not in furniture.

Brooklyn, N. Y., August, 1937.—Have been combating psocids in new apartment houses. Have always been successful with paradichlorobenzene, but this method takes from three to four weeks and tenants do not like to be bothered so long.

Rochester, N. Y., August, 1937.—A Federal Housing Administration mortgagee has become much alarmed owing to the attitude taken by one of the mortgagors concerning psocids which have invaded a newly constructed home. This lending institution would like to know definitely whether or not these insects do any damage to the structure that might seriously impair its stability or value.

New York City, September, 1937.—Lawyer writes for copies of psocid bulletin for distribution to clients in apartment house infested with psocids.

New Jersey, October, 1937.—Sold a three-piece living-room suite of upholstered furniture to a dealer who after 60 days sold it to a customer. Thirty days after the second sale psocids were abundant on furniture. No insects had been observed previously. Who is responsible for infestation?

New York City, November, 1937.—Psocids overrunning apartment house completed 2 months ago.

New Jersey, December, 1937.—New detached home completed in April was heavily infested with psocids during the summer, which was reported as abnormally humid. House overrun with visible molds. Furnace heat dried up molds and probably destroyed psocids, as they have disappeared.

Iowa, July, 1938.—Never discovered harm caused by psocids. By the use of an oil spray am able to destroy psocids on surfaces, but afterwards discover more insects on these surfaces.

New York City, July, 1938.—A new building completed and occupied since March became infested with psocids during June and July. The insects annoy the tenants. Exterminators have tried everything and we have gone to great expense but psocids continue to multiply.

Bronx, New York City, July, 1938.—Have moved into a new building, being the first tenants. It is overrun with psocids.

New York City, August, 1938.—Psocids are seen only in newly constructed buildings, and the belief among pest control operators is that psocids come from diseased unseasoned wood.

Connecticut, August, 1938.—Living-room suite of upholstered furniture found heavily infested with psocids. Sprayed with 2 quarts of spray and kept room tightly closed but still the psocids come. Furniture 15 years old and room very damp.

Idaho, August, 1938.—Last winter was so mild that psocids did not die off as usual and now they are a great deal worse than last year. Insect powder doesn't kill them. Sprays kill only those on the walls. Had the house fumigated but the psocids came back.

South Dakota, September, 1938.—Myriads of psocids infesting country homes. Sulfur fumigation is ineffective. Hydrocyanic acid gas gives good results.

Pennsylvania, November, 1938.—A 22,700-cubic-foot house fumigated with hydrocyanic acid gas in September at a

cost of $50 was found 10 days later to be infested. Refumigated three times at 10-day intervals during October and now house seems free of psocids, but owner believes that cold weather came to his assistance.—4-24-39.

LITERATURE CITED

Candura, G. S. 1932. Contributo alla conoscenza biologica del *Troctes divinatorius* (Müll.) Bol. Zool. 3(4):177–84. Illus.

Finlayson, L. R. 1932. Some notes on the biology and life history of psocids. Ent. Soc. Ontario Ann. Rept. 63. 64 pp., illus.

Rosewall, O. W. 1930. The biology of the book-louse, *Troctes divinatorius*, (Müll.). Ann. Ent. Soc. Amer. 23(1):192–4. Illus.

Fluorine Spray Residue Removal With Dilute Solutions of Hydrochloric Acid, Boric Acid and Sodium Chloride*

ERROL HAY KARR,†‡ *Tacoma, Wash.*

The use of natural cryolite as an insecticide for combating the codling moth on apples has been general in the Pacific Northwest since importance was given this material through the field experiments of Newcomer & Carter (1933). Because of the increased use of this product, field experiments in the removal of fluorine residues from apples were made in the Wenatchee and Yakima districts in the state of Washington during the 1936–37 season. The results of some of these experiments are given in this paper.

Natural cryolite is known chemically as sodium aluminum fluoride (Na_3AlF_6). Its insecticidal properties are attributed to its fluorine content. All of the natural cryolite in commercial use comes from deposits in Greenland and is pulverized extremely fine for use as an insecticide. Some interesting properties of this specially prepared product were described by Underwood (1935). The natural cryolite insecticide is applied to apples as a suspension in water, generally in combination with a suitable amount of mineral oil emulsion or fish oil, which makes possible a greater and more lasting deposit. Heavier spray deposits of this insecticide, when properly applied, invariably result in more effective codling moth control, but, usually as a result of the heavier deposits, the removal of the spray residue from harvested fruit by various washing methods may be more difficult.

Other than in a few exceptional cases, natural cryolite was applied during the late summer to control the second brood codling moth larvae. In the majority of cases, lead arsenate was applied to control the first brood infestation. The average spray schedule in which natural cryolite was used included two or three applications of this material, generally during the months of July and August. In a small number of cases four or five applications of natural cryolite were made, the first of which was applied during the first part of June. There were also a few growers who used natural cryolite in their orchards exclusively throughout the season.

Spray deposits containing fluorine are expressed generally in terms of "grains of fluorine per pound of fruit." This terminology will be used throughout this discussion.

PROBLEMS AND EXPERIENCES IN FLUORINE SPRAY RESIDUE REMOVAL.—The fluorine spray deposit on the different lots of unwashed, natural cryolite sprayed fruit generally varied from 0.05 to 0.3 grain per pound. During the 1936–37 season, the federal government tolerance for fluorine spray residues‡ was 0.01 grain per pound of fruit and vegetables. In order to comply with this tolerance, and to make shipments legally in interstate commerce, it was necessary to reduce the fluorine spray residue on unwashed fruit which had been sprayed with natural cryolite.

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† Technical Department, Pennsylvania Salt Manufacturing Company of Washington, Tacoma, Wash.

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‡ In November, 1938, the federal government tolerance for fluorine spray residues on fruit and vegetables was increased to 0.02 grain per pound.

The various problems and methods concerning the removal of fluorine spray residues had been discussed by a number of investigators prior to 1937 (Smith, Ryall *et al.* 1933, 1934; Carter 1934, 1935; Haller, Smith & Ryall 1935; Karr 1935; and Groves, Marshall *et al.* 1936). In the Wenatchee district, one of the most effective commercial methods for removing fluorine spray residue was by use of the so-called double process, overhead, flood type fruit washer, such as the one described by Overley *et al.* (1933) and illustrated by Robinson (1936). When machines of this type are equipped with cross-underneath rotating brushes, the fruit cleaning effectiveness is still further increased. However, as yet not many machines of this brush type have been used, but it appears that they may become more popular in the future. In the first wash, sodium silicate (1 Na_2O: 1.6 SiO_2) was used, generally at the rate of 60 to 80 pounds to each 100 gallons of water. In the second wash hydrochloric acid was used at concentrations varying from 1.25 to 1.75 per cent by weight. Light grades of mineral oil were sometimes added to the acid bath and found to be helpful in washing certain lots of fruit that were difficult to clean.

The temperatures of the washing solutions employed generally ranged from 100 degrees to 115 degrees F. for the sodium silicate solution, and 90 degrees to 110 degrees F. for the acid bath. The average length of the exposure of the fruit to each heated chemical solution ranged from 20 to 40 seconds.

BORIC ACID AND SODIUM BORATE IN THE REMOVAL OF FLUORINE SPRAY RESIDUES.—In a number of cases, from 1 to 2 per cent of boric acid was included in the hydrochloric acid solutions in an attempt to increase the solubility rate of the fluorine spray residues. A public patent has been granted to Carter & Fahey (1936) on the use of boric acid in aqueous solutions for hydrochloric or sulfuric acid for the removal of fluorine spray residues from fruits and vegetables.

It was reported by Carter (1934) that the addition of 1 gram of boric acid to 100 cubic centimeters of 1.5 per cent hydrochloric acid solution at 20 degrees C. increased the solubility of the cryolite* from 0.2404 gram of fluorine to 0.5576 gram of fluorine. Laboratory results indicate that the solubility of cryolite in a 2 per cent solution of boric acid alone is not so great as when hydrochloric acid is present.

It was during the 1936 season that boric acid was first employed in the Wenatchee and Yakima districts for removing fluorine spray residues from apples on a commercial scale. In the majority of cases where it was used, 16 to 20 pounds were added to each 100 gallons of acid washing solution.

Most of the fruit washing operators using boric acid tested the solution for this ingredient at the beginning or end of a day's run. Some operators added a few pounds of boric acid every few hours or so in an attempt to maintain the boric acid concentration. In this manner some of them managed to maintain a fairly consistent boric acid content.

The results from the addition of boric acid to the hydrochloric acid solution in commercial machines early in the season indicated in some cases that it aided in the removal of fluorine spray residues. Further commercial experiences also indicated that the addition of boric acid in excess of 2 or 3 per cent to the acid bath was unnecessary.

More benefits from the use of boric acid in hydrochloric acid solutions were realized in removing fluorine spray residues from the early varieties of apples, when it was not necessary to use washing temperatures in excess of 100 degrees F. However, in washing the later, more heavily waxed varieties of fruit that necessitated the use of higher temperatures, the presence of boric acid in the hydrochloric acid solution of a double process fruit washer did not seem to be so effective as first expected. While it was not so easy to clean the fruit with a single process fruit washer, it was indicated that better results might be obtained from the addition of boric acid to the hydrochloric acid solution. However, the majority of fruit washers used in packing plants at Wenatchee and Yakima are of the double process type.

In several cases during the fruit washing season in the Wenatchee district, borax (sodium tetraborate, $Na_2B_4O_7 \cdot 10\ H_2O$) was tried as a source of boric acid by a number of individuals not ac-

* Literature cited does not state whether cryolite was of synthetic or natural origin.

quainted with the chemical properties of this compound as compared with boric acid. The borax was added to the hydrochloric acid solution in sufficient quantities to give the desired boric acid content. Since borax is an alkaline compound, the addition of it to the acid bath reduced the hydrochloric acid concentration, and it was therefore necessary to add more acid to replace that lost.

In several instances where borax was tried as a source of boric acid in hydrochloric acid solutions commercially, difficulties resulted in the removal of fluorine spray residues, particularly if the solution temperatures employed were not much in excess of 100 degrees F. It was indicated that the poorer results obtained with the use of borax as a source of boric acid in the solution at the above tempera-

Table 1.—Description of apple samples.

LEGEND	VARIETY	ORIGINAL RESIDUE*	SPRAY PROGRAM† (Lead arsenate was used as a calyx spray in each case)
F	Yellow Newtowns	0.18	1–2–3 cover sprays: lead arsenate 4–5–6 cover sprays: natural cryolite‡ (3 pounds plus 1 quart mineral oil emulsion**)
H	Winesaps	0.12	1–2–3–4 cover sprays: lead arsenate 5–6 cover sprays: natural cryolite (3 pounds plus ½ gallon mineral oil emulsion#)
K	Winesaps	0.17	1–2–3 cover sprays: lead arsenate 4–5–6–7–8– cover sprays: natural cryolite (2½ pounds plus ⅔ pint fish oil##)
L	Arkansas Blacks	0.18	Same as for K

* Average of quadruple analysis.
† The amount of natural cryolite or sticker compound used to each 100 gallons of spray given.
‡ *Kryocide*, manufactured by Pennsylvania Salt Manufacturing Company.
** Mineral oil emulsion *Orthol-K-Medium*, manufactured by the California Spray-Chemical Corporation.
# Mineral oil emulsion *Treoil*, manufactured by Oil Sprays, Inc., Yakima, Wash.
Herring oil. (Cloud point not over 65 degrees F. Iodine number approximately 135. Free fatty acid content 1–2 per cent).

In the addition of borax to the hydrochloric acid bath, boric acid and sodium chloride are formed, and this chemical reaction may be represented by the following equations:

$$Na_2B_4O_7+2HCl=H_2B_4O_7+2NaCl$$
$$H_2B_4O_7+5H_2O=4H_3BO_3.$$

To make a solution of equal boric acid content, it will take approximately one and one-half times more borax by weight than boric acid. When borax is used approximately 1 per cent sodium chloride will result for each 2 per cent boric acid formed.

In laboratory experiments, Carter (1934) found that the solubility of cryolite† in 100 cubic centimeters of 1.5 per cent solution of hydrochloric acid at 20 degrees C. was reduced on the addition of 2 grams of sodium chloride from 0.2404 gram of fluorine to approximately one-half that amount.

† Literature cited does not state whether cryolite was of synthetic or natural origin.

tures were more noticeable when single process fruit washers were employed. This lowered efficiency of the acid in removing fluorine spray residues was attributed to the sodium chloride formed by the addition of the borax. It was stated by Ryall (1934) that sodium chloride should not be added to the hydrochloric acid solutions used for fluorine spray residue removal.

A number of special observations were made of the fruit washed in hydrochloric acid solutions containing boric acid to find out whether or not this mixture was injurious to the fruit. During the packing season of 1936–37, no fruit washing injury could be traced directly to the use of boric acid in the acid bath. It is, however, highly recommended that the last traces of boric acid and hydrochloric acid be removed by thorough rinsing with clean water.

FRUIT USED IN EXPERIMENTS.—The fruit of lots bearing the code of letters *F*, *K* and *L* were grown and sprayed in

Wenatchee, and the fruit of code *H* was from Yakima. The fruit of all four lots had been sprayed with lead arsenate early in the season, followed by the use of natural cryolite according to the schedules shown in table 1.

FRUIT WASHING EQUIPMENT USED IN EXPERIMENTS.—A single process, "overhead flood type," fruit washer was used in treating all of the fruit samples. A single process fruit washer was found to be more suitable for determining the relative effectiveness of the various acid solutions to be tried on the fruit used. A double process fruit washer would have reduced the fluorine spray residue to a point where it would have been more difficult to make any comparisons of the results obtained.

A print of the single process fruit washer is shown in fig. 1. This is the same make of machine used in the fluorine spray residue experiments and is classified by the manufacturer* as the *Cutler-Moe Growers Model "B"* fruit washer. The length of the model without the dryer, including motor, is approximately 14.5 feet. A detailed diagram showing the construction and operation of a larger model of the same make of fruit washer is given by Robinson (1936). The principles of operation of a single unit of the larger fruit washer are similar to those employed in the smaller model.

The fruit washer used in these experiments was located in a grower's packing shed on a ranch in Wenatchee. It was checked mechanically, and all necessary repairs were made to insure proper working order for the experiments.

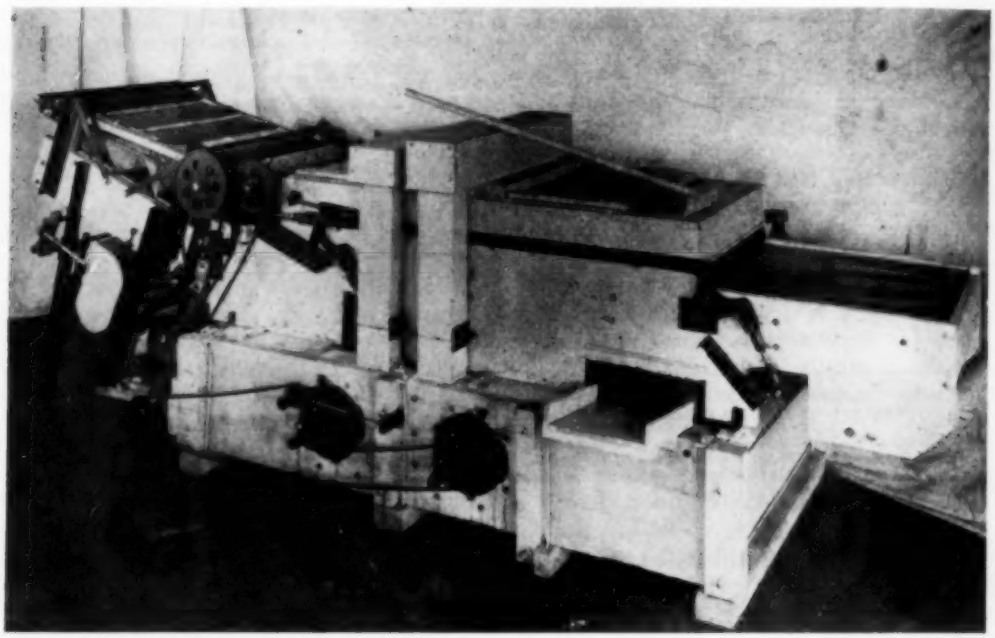


FIG. 1.—View of the type of fruit washer used in the fluorine spray residue removal experiments. (Courtesy of Cutler Manufacturing Co., Portland, Ore.)

When the fruit washer is in operation, the fruit is unloaded on to a series of descending rubber covered bars that permit the fruit to roll onto a "push over type" conveyor, which, in the *Model "B,"* is approximately 32 inches in width. Any leaves or twigs mixed with the fruit are eliminated through the bars as the fruit rolls forward. The "push over type" conveyor consists of two series of crosswise wooden members with side surfaces at a 45 degree angle. Every other member moves up and down for a short distance and edges the fruit forward on the upward stroke from valley to valley. The purpose of this conveyor is to turn the fruit as it is carried forward, so that all

* Cutler Mfg. Co., Portland, Oregon.

the sides will be exposed to the flood of washing solution or rinse water from the overhead section of the fruit washer. The turning of the fruit also minimizes the carry-over of the acid solution to the rinse section.

The washing section of the machine is equipped with a rectangular wooden tank having a capacity of 200 gallons. Connected to this tank is a centrifugal pump capable of lifting approximately 500 gallons of solution per minute to the overhead section where it is uniformly distributed and permitted to flow through slats on to the fruit conveyor below. The length of travel for fruit under the flood of washing solution is about 32 inches, and the time required for the fruit to pass through is approximately 34 seconds. From the first section, the fruit is then subjected to a fresh water rinse in a similar manner as applied to the washing solution treatment, with the exception that the length of travel in the rinse is 16 inches.

From the rinse section, the fruit is brought in contact with what might be termed a "walking conveyor," which consists of two series of longitudinal boards with wavelike upper surfaces. One of the series is stationary and the other has an oscillating motion. In this manner the fruit is lifted gently from one valley to the next on a slight incline. The fruit is turned as it travels forward and is brushed with absorbent cloth streamers constituting the section known as the dryer. The purpose of this treatment is to remove droplets of water that cling to the fruit as it leaves the rinsing chamber. On the lower end of the dryer the velvet streamers are passed through a roll which removed the excess water collected.

EXPERIMENTAL PROCEDURE. — The washing solution in the fruit washer was heated by the direct introduction of steam through a section of rubber hose that was immersed in one corner of the tank. The steam was regulated by a suitable valve located within easy reach. The temperatures of the acid solution were determined with two laboratory stem thermometers, one of which was kept immersed in the tank at all times, and only partially removed when the readings were taken. The other stem thermometer was used for taking temperatures of the solution in the overhead flood section where it was raised from the tank by a centrifugal pump. In this manner, it was believed, a better temperature control could be obtained. The fruit samples were not washed until the temperatures taken in both the lower and overhead sections agreed.

A commercial grade of hydrochloric acid (muriatic acid), powdered boric acid and borax were used in the preparation of the various washing solutions. The powdered boric acid or the borax was added to the acid solution in the overhead section of the fruit washer while in operation. The solubility of boric acid in hydrochloric acid solutions at the concentrations and temperatures commonly used for washing fruit is shown in fig. 2.

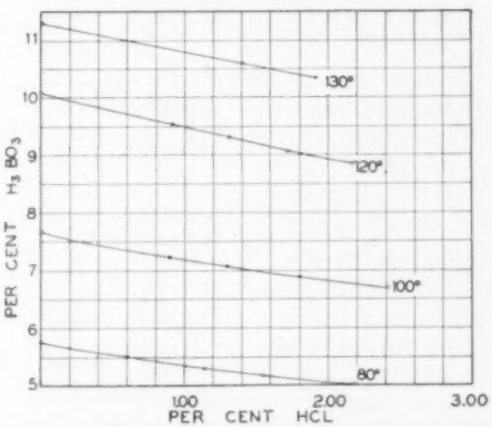


FIG. 2.—Solubility of boric acid in dilute hydrochloric acid solutions. (Courtesy Pacific Coast Borax Co., Wilmington, Cal.)

The concentration of the hydrochloric acid, and the amount of boric acid in solution were determined by titrating with 0.1 normal sodium hydroxide. A 10 milliliter aliquot of the solution was taken, and with methyl orange as an indicator, the standardized sodium hydroxide solution was added to determine the hydrochloric acid concentration. If boric acid was to be determined, the titration was continued in the presence of phenolphthalein indicator and neutral glycerol, according to the method given by Mahin (1932).

The sodium chloride in the acid solutions to which borax had been added was determined first by titrating the hydrochloric acid as described above, and from this the amount of chlorine as such was calculated. The total amount of chlorine

was then determined by the Mohr method in a neutralized sample by titrating with a standard silver nitrate solution in the presence of a chromate indicator as described by Sutton (1935). The amount of chlorine calculated as hydrochloric acid was deducted from the total chlorine found and, from the remaining figure, the amount of sodium chloride was calculated.

of lot *H* in cold storage (30 degrees F.) prior to the washing experiments.

Four separate samples of approximately 50 apples were taken from each lot for the different washing treatments. When small quantities of fruit are washed in commercial machines, some of the fruit may lag behind in its travel. The delay of any of the fruit in a sample will introduce errors in the spray residue removal comparisons.

Table 2.—Results obtained in the washing of the four different lots of fruit by the various treatments.

Washing Solutions Used (Approximately 200 gallons)	Fluorine Residue, Grains Per Pound of Fruit							
	100 degrees				110 degrees			
	F	*H*	*K*	*L*	*F*	*H*	*K*	*L*
HCl 1.5 per cent*	0.010	0.008	0.009	0.010	0.006	0.006	0.006	0.010
	0.011	0.010	0.009	0.013	0.007	0.007	0.007	0.010
	0.011	0.010	0.011	0.014	0.007	0.009	0.008	0.010
	0.012	0.012	0.013	0.015	0.010	0.011	0.009	0.013
Av.	0.011	0.010	0.011	0.013	0.007	0.008	0.008	0.011
HCl 1.5 per cent H_2BO_3 2.2 percent†	0.006	0.008	0.010	0.011	0.006	0.006	0.007	0.005
	0.007	0.008	0.012	0.012	0.006	0.007	0.007	0 008
	0.008	0.010	0.012	0.013	0.008	0.008	0.008	0.008
	0.008	0.011	0.013	0.014	0.008	0.008	0.009	0.009
Av.	0.007	0.009	0.012	0.013	0.007	0.007	0.008	0.008
HCl 1.5 percent	0.014	0.012	0.016	0.015	0.008	0.007	0.007	0.007
H_2BO_3 2.0 per cent‡	0.017	0.013	0.016	0.017	0.008	0.007	0.007	0.007
NaCl 1.1 per cent	0.017	0.015	0.016	0.017	0.009	0.008	0.009	0.007
	0.021	0.019	0.016	0.019	0.011	0.008	0.009	0.008
Av.	0.017	0.015	0.016	0.017	0.009	0.008	0.008	0.007

Av. = Average
HCl = Hydrochloric acid
H_2BO_3 = Boric acid
NaCl = Sodium chloride

* Approximately 8½ gallons of commercial grade hydrochloric acid (muriatic) of 31 per cent strength were required.

† Approximately 38 pounds of a commercial grade of powdered boric acid were added to the hydrochloric acid solution.

‡ Approximately 57 pounds of borax (sodium tetraborate) were added to the 200 gallons of 1.5 per cent hydrochloric acid solution. This combination reacts chemically, forming boric acid and sodium chloride according to the following equation: $Na_2B_4O_7 + 2HCl + 5H_2O = 4H_3BO_3 + 2NaCl$. As a result of this reaction, the hydrochloric acid concentration was reduced to about 0.5 per cent. It was necessary to add approximately 5½ gallons of hydrochloric acid to the washing solution to bring the concentration back to 1.5 per cent.

The concentrations and temperatures of the solutions used in the experiments are shown in table 2. The concentration of the washing solutions was determined just before and after each separate lot of fruit was washed. The change in the solution constituents during the washing of the sample was found to be negligible. After each lot, consisting of four samples, was washed a quart of the solution was collected in clean bottles and retained for laboratory analysis later.

The fruit washing experiments were made approximately two weeks after the picking dates. The fruit of lots *F*, *K*, and *L* were kept in common storage and that

In order to avoid this, each experimental sample of fruit was immediately followed by a suitable quantity of an odd variety to act as "chasers." The fruit of each sample was counted before and after being washed to make sure that all of it had left the fruit washer.

The performing of the washing experiments required the attention of two men. A number of the unwashed fruit samples were prepared ahead of time so that there would be no unnecessary delay during the washing procedure. The individual handling the unwashed fruit was careful not to handle any of the washed fruit before cleaning his hands. Each sample

of washed fruit was immediately transferred from the fruit washer to labeled, clean paper bags. The paper bags containing the samples were then carefully packed into wooden boxes and sealed for shipment to the cold storage plant where they were to be held until withdrawn by the laboratory for fluorine spray residue analyses.

In the selection of fruit for fluorine spray residue analyses, a suitable quantity was taken from each of the four separate samples of the different lots washed by the treatments shown in table 2. It has been found in previous experiments that from 30 to 70 per cent of the spray residue is in the stem and calyx ends of the fruit, and for this reason an equal number were used in each sample taken for analysis. In order to keep the weight of each sample between 1,200 and 1,500 grams, 10 was selected as the standard number of fruit.

METHOD OF ANALYZING FRUIT SAMPLES FOR FLUORINE SPRAY RESIDUES.—The laboratory method used for determining the fluorine spray residue on apples was one especially developed for this purpose by the Food and Drug Administration (1935). The determination of small quantities of fluorine in the presence of organic matter is subject to considerable variation unless the procedure is carefully controlled. The organic matter of the sample in the case of analyzing apples is greatly reduced by using only the skins and the stem and calyx sections of the fruit in the analysis. An experienced analyst is able to obtain quite satisfactory results, as rechecks of the laboratory routine have verified. However, it is believed that too much reliance should not be placed on single determinations because of the number of factors involved other than those connected with the laboratory procedure, and for this reason four analyses were made on every lot of fruit washed by each of the different treatments shown in table 2.

DISCUSSION OF RESULTS.—The fluorine spray residue removal results of the samples washed in the different solutions at temperatures of 100 degrees and 110 degrees F., respectively, are given in table 2.

By studying table 2, it is evident that a definite improvement in the removal of the fluorine spray residues was obtained by increasing the heat of the different washing solutions from a temperature of 100 degrees to 110 degrees F. The increased effectiveness on raising the temperatures was particularly noticeable with the hydrochloric–boric acid washing solutions containing sodium chloride.

With the exception of lot *F*, the results obtained at a temperature of 100 degrees F. with hydrochloric–boric acid solutions were approximately the same as those obtained by using only hydrochloric acid in the wash. The improvement in results obtained by washing lot *F* with the addition of boric acid might be attributed to the kind of spray schedule used and the lighter coating of natural wax noticeable on the fruit.

The results obtained in washing the fruit of lot *L* with hydrochloric–boric acid solutions at a temperature of 110 degrees F. were lower than those obtained by using only hydrochloric acid in the wash. In the case of washing the fruit of lots *F*, *H* and *K* at 110 degrees F., the addition of boric acid did not result in any definite improvement. In the hydrochloric acid solution, to which borax had been added, the amount of sodium chloride formed noticeably reduced the effectiveness of the washing treatment in every case at a temperature of 100 degrees F., but not when a solution temperature of 110 degrees F. was used, except in the case of cleaning the fruit of lot *F*. The only solution which consistently reduced the fluorine spray residue in every sample below the 1936–1937 government tolerance of 0.01 grain of fluorine per pound was the hydrochloric acid wash at a temperature of 110 degrees F., to which boric acid had been added. However, the difference was too slight to attribute this definitely to the presence of boric acid.

SUMMARY.—In the removal of fluorine spray residues from apples with a single process, overhead flood type fruit washer, the presence of 2 per cent boric acid in a 1.5 per cent solution of hydrochloric acid at a temperature of 100 degrees F. was only slightly, if at all, more effective than the hydrochloric acid solution alone. The effectiveness of a 1.5 per cent solution of hydrochloric acid containing 2 per cent boric acid was reduced considerably by the presence of 1 per cent sodium chloride at a solution temperature of 100 degrees F. When the temperature of the hydrochloric–boric acid solution containing 1

per cent sodium chloride was increased to 110 degrees F., the depressing action of the sodium chloride was prevented.—5-1-39.

LITERATURE CITED

Carter, R. H. 1934. Solvents for cryolite. JOUR. ECON. ENT. **27**(4):863. Aug.

Carter, R. H. 1935. An investigation of solvents for the removal of insecticidal fluorine residues from fruits. JOUR. ECON. ENT. **28**(5):829–31. Oct.

Carter, R. H., and J. E. Fahey. 1936. Process for the removal of insecticidal residues from fruits and vegetables. U. S. Patent 2,046,548. July 7.

Food and Drug Administration. 1935. Revised rapid method for determination of fluorine spray residues on apples and pears. Feb. 15. Mimeographed.

Groves, Kermit, R. E. Marshall, F. L. Overley and J. L. St. John. 1936. The removal of fluorine spray residue from apples sprayed with natural cryolite. Wash. Ag. Exp. Sta., Bul. **329.** 15 pp.

Haller, M. H., Edwin Smith and A. L. Ryall. 1935. Spray-residue removal from apples and other fruits. U. S. Dept. Ag. Farmers' Bul. **1752.** 25 pp.

Karr, E. H. 1935. Preliminary experiments in the removal of fluorine residue. Better Fruit Mag., Oct.–Nov.

Karr, E. H. 1935. Discussion of the residue removal of fluorine sprays. Wash. State Hort. Assoc. Proc. 31st Ann. Meeting: 119–25.

Mahin, Edward G. 1932. Quantitative naalysis, pp. 213–17. McGraw-Hill Book Co. New York. Fourth Ed.

Newcomer, E. J., and R. H. Carter. 1933. Studies of fluorine compounds for controlling the codling moth. U. S. Dept. Ag. Tech. Bul. N. **373.** 22 pp.

Overley, F. L., J. L. St. John, E. L. Overholser and Kermit Groves. 1933. Lead and arsenic spray residue removal from apples. Wash. Ag. Exp. Sta., Tech. Bul. **286,** June. 83 pp.

Robinson, R. H. 1936. Spray residue on apples. Ind. Eng. Chem. **28**(4):455–7. April.

Ryall, A. L. 1934. Discussion, fluorine spray residue removal. Wash. State Hort. Assoc., Proc. 30th Ann. Meeting: 86–7.

Smith, Edwin, A. L. Ryall, C. R. Gross, R. H. Carter, C. W. Murray and J. E. Fahey. 1933. The removal of lead, arsenic and fluorine residues from apples. Wash. State Hort. Assoc., Proc. 29th Ann. Meeting: 86–96.

Smith, Edwin, and A. L. Ryall. 1934. Recent experiments on the removal of lead, arsenic and fluorine residues from apples. Idaho State Hort. Assoc. 39th Ann. Meeting: 35–40.

Sutton, Francis. 1935. Volumetric analysis, pp. 136–39. P. Blakiston Son & Co., Inc. Philadelphia, 12th Ed.

Underwood, J. E. 1935. Description of the fluorine insecticide, *Kryocide.* Better Fruit Mag., p. 10. Sept.

Volatile Oils as Ovicides for the Screwworm, *Cochliomyia americana* C. & P.*

RAYMOND C. BUSHLAND, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

In previous investigations† it had been found that oil of wormseed was effective against the eggs of *Cochliomyia americana* C. & P. Tests were therefore conducted at the Menard, Tex. laboratory to determine whether certain common volatile (essential) oils, as listed in the Dispensatory of the United States of America, edition 22, 1937, are ovicidal to this insect.

Eggs were obtained by confining flies in cotton-plugged specimen tubes containing small pieces of fresh lean beef (Melvin 1937). The flies were of the forty-first to forty-ninth consecutive generations reared on an artificial medium, a modification of that described by Melvin & Bushland (1936). Oviposition occurred over a period of about 2 hours; therefore in each lot of eggs the degree of embryonic development varied.

The eggs were divided into two classes, (a) those less than 3 hours old and (b) those within about 2 hours of hatching. Each oil was tested by dipping it in at least 10,000 eggs of each class. The testing procedure for each class of eggs was as follows: An estimated 5,000 eggs were dipped in the oil. At a later date another lot of 5,000 eggs, from a different culture of flies, was dipped. If there was much variation in the results of the two tests, a third lot of 5,000 eggs, from another culture of flies, was dipped to further establish the

* Early publication of this paper has been secured by payment of the printing charge.

† Unpublished data by Melvin & Bushland.

Table 1.—Ovicidal effectiveness of some common volatile oils tested on *Cochliomyia americana*.

VOLATILE OIL	WEIGHTED MEAN PERCENTAGE OF HATCH	
	Eggs Less Than 3 Hours Old	Eggs Within 2 Hours of Hatching
Anise	0	0
Bay	0	21
Bergamot	0	15
Bitter almond	0	0
Cajuput	0	34
Calamus	75	100
Caraway seed	0	0.5*
Cassia	0	0
Cedarwood	80	100
Citronella	0	64
Clove	0	4*
Coriander	0	43
Cubeb	50	100
Cumin seed	0	0.5
Eucalyptus	3	50
Fennel seed	0	0
Ginger	25	100
Juniper berry	13	100
Lavender	0	25
Lemon	0	3
Lemongrass	0	8*
Matico	5	100
Mustard	0	0
Parsley	0	0
Pennyroyal	0	0
Peppermint	0	29
Pine needle	0	100
Rosemary	0	60
Rue	0	0
Sassafras	0	0
Savin	0	100
Spearmint	0	51
Sweet birch	0	0
Sweet orange	0	55
Turpentine	9	93
Verbena	0	80
Wormwood	0	90

* Larvae died almost immediately after hatching.

toxicity of the oil. From every stock of eggs used for dipping, a 5,000-egg sample was left untreated as a check. On the rare occasions when these check eggs failed to hatch 100 per cent, tests with eggs of that stock were discarded.

The method of testing was as follows: An egg mass lightly held with fine-pointed forceps was momentarily immersed in the oil to be tested. Dipped masses were placed on blotting paper and allowed to dry for 30 minutes at room temperature. The eggs were then transferred to wet filter paper in open Petri dishes, which were placed over water in covered 5-gallon crocks to provide proper humidity. Records of the percentage of hatch were taken at least 4 hours after hatching was completed in the check lots. These percentages were based on an estimate of the number of eggs that hatched from each lot.

The results of these tests are presented in table 1.

SUMMARY.—Thirty-seven volatile oils have been tested as ovicides on *Cochliomyia americana* C. & P., the eggs being divided into two classes according to age.

Oils of anise, bitter almond, cassia, fennel seed, mustard, parsley, pennyroyal, rue, sassafras and sweet birch killed all eggs in the two classes.

Oils of caraway seed, clove and lemongrass, although they did not entirely prevent hatching of the older eggs, caused the larvae to die almost immediately after hatching.

The younger eggs were more easily destroyed than the older eggs, for in addition to all the oils mentioned above, oils of bay, bergamot, cajuput, citronella, coriander, cumin seed, lavender, lemon, peppermint, pine needle, rosemary, savin, spearmint, sweet orange, verbena and wormwood were completely effective against the younger eggs.—5-2-39.

LITERATURE CITED

Melvin, R., and R. C. Bushland. 1936. A method of rearing *Cochliomyia americana* C. & P. on artificial media. U. S. Dept. Ag., Bur. Ent. & Pl. Quar. Mimeo. Cir. ET-88. Aug.

Melvin, R. 1937. *Cochliomyia americana* and *C. macellaria*. In Culture methods for invertebrate animals, pp. 413–4. Comstock Publishing Co., Ithaca, N. Y.

ALL Wyoming quarantines relating to the alfalfa weevil were revoked on October 1, 1938, the weevils having been found generally distributed over the state.

THE state of Utah on March 16 adopted the standardized 1939 peach mosaic quarantine, which requires as a condition of certification of all permitted host plants shipped into or within the state the removal by May 15 of all diseased trees in a radius of 1 mile of the nursery or budwood source, and subsequent fall inspection, no certificates to be issued within a year after the finding of the disease in or adjacent to the nursery or budwood orchard.

Studies With Dinitro-O-Cyclohexylphenol*†

A. M. Boyce, J. F. Kagy,‡ C. O. Persing and J. W. Hansen,**
University of California Citrus Experiment Station, Riverside

Since 1935, dinitro-o-cyclohexylphenol has been included in insecticide investigations pertaining to the control of citrus and other subtropical fruit insects and mites. The work with this particular compound has necessarily been somewhat limited and of an exploratory nature. The studies have consisted primarily of toxicity experiments on several important insects and mites. Certain phases of the physical and chemical properties of the compound that may be related to field usage have been investigated.

Literature.—The more pertinent older literature pertaining to nitro-phenols as insecticides has been so recently reviewed by Kagy & Richardson (1936) that a further review at this time seems unnecessary.

The work of Kagy & Richardson (1936) and Dutton (1936) has shown that dinitro-o-cyclohexylphenol, when incorporated in dormant oil sprays, offers considerable promise in the control of the San José scale, *Aspidiotus perniciosus* Comst.; the rosy apple aphid, *Anuraphis roseus* (Baker); and the black cherry aphid, *Myzus cerasi* (F.). From the published data, it appears that this compound, when incorporated in a dormant oil, is at least as effective as the conventional tar-petroleum-oil dormant sprays.

Kagy (1936) has investigated the effectiveness of some nitro-phenols as stomach poisons for several species of insects. His data show that to the corn ear worm, *Heliothis obsoleta* (F), dinitro-o-cyclohexylphenol and its calcium, magnesium, lead and copper salts are several times more toxic than acid lead arsenate. Of the salts considered, Kagy found that the calcium salt was the most toxic. It was slightly more toxic to the imported cabbage worm, *Pieris rapae* (L.), about 4.4 times more toxic to the corn ear worm and 17 times more toxic to the armyworm, *Cirphis unipuncta* (Haw.), than acid lead arsenate.

Hansberry & Richardson (1936) presented comparisons between the medium lethal dosages of various compounds, including dinitro-o-cyclohexylphenol and its calcium salt, on the larva of the silk worm, *Bombyx mori* L., the painted lady, *Vanessa cardui* (L.), and certain other species. There compilations concerning the silkworm show that certain of the derris derivatives, namely, rotenone, dihydrorotenone, deguelin and tephrosin, were the most toxic of the materials upon which data are available. Dinitro-o-cyclohexylphenol and its calcium salt were next to the derris derivatives in toxicity. They were more toxic than the arsenious and arsenic anhydrides, the dyes (malachite green, safranin bluish, brilliant green and crystal violet), acid lead arsenate, and the fluosilicates and fluoaluminates. The foregoing materials are listed in order of decreasing toxicity. Dinitro-o-cyclohexylphenol and its calcium salt were both more toxic to *Vanessa cardui* than rotenone or acid lead arsenate.

Boyce & Prendergast (1936) reported promising results with dinitro-o-cyclohexylphenol in the control of several important pests of citrus and other subtropical crops.

Hartzell & Moore (1937) used dinitro-o-cyclohexylphenol dissolved in dormant lubricating oil sprays for the control of the oystershell scale, *Lepidosaphes ulmi* (L.) on apple. They obtained excellent results in the control of this insect, using an emulsion of 4 per cent lubricating oil which contained 4 per cent of the nitrophenol in solution.

Hammer (1938), working on the overwintering eggs of the scurfy scale, *Chionaspis furfura* (Fitch), reported results from lubricating oil emulsions containing dinitro-o-cyclohexylphenol which indicated that this combination is at least as toxic as tar–lubricating oil emulsions.

Hartzell *et al.* (1938), in field experiments on the control of the eye-spotted budmoth, *Spilonota ocellana* (D. & S.), found that effective control can be secured by the use of lubricating oil containing dinitro-o-cyclohexylphenol. Optimum efficiency was obtained from the lubricating oil emulsion when 3 per cent

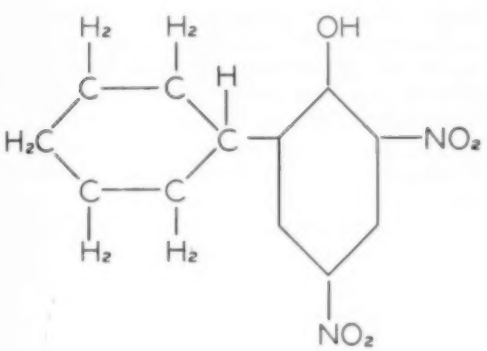
* Paper No. 397, University of California Citrus Experiment Station, Riverside.
† Early publication of this paper has been secured by payment of the printing charge.
‡ Investigator for the Crop Protection Institute.
** Formerly assistant in research.

of the nitro-phenol was dissolved in the oil. Equal concentrations of the nitro-phenol and oil in diluted spray emulsions gave similar results regardless of the manner of preparation or kind of emulsion used.

Garman (1938), in experiments conducted since 1936, has found that a lubricating oil emulsion containing 4 per cent dinitro-o-cyclohexylphenol dissolved in the oil is as toxic to eggs of the rosy apple aphid, *Anuraphis roseus*, as a tar oil emulsion of equal oil concentration.

In the various studies of dinitro-o-cyclohexylphenol, dealing with a number of species of insects and mites, where the compound has been employed either as a contact or stomach poison, it has not exhibited the marked specificity of action that is fairly common to organic insecticides.

PHYSICAL AND CHEMICAL PROPERTIES.—Dinitro-o-cyclohexylphenol, more specifically 2-4-dinitro-6-cyclohexylphenol, has the following structural formula:



DINITRO-O-CYCLOHEXYLPHENOL

It is a nearly odorless, yellowish-white crystalline compound having a molecular weight of 266. It crystallizes in needles from alcohol and certain other solvents including petroleum oils, and in hexagonal plates from acetone. After recrystallization from alcohol, the melting point is 106 degrees C.; however, the technical grade material that is available for use as an insecticide is slightly impure.

The substitution of nitro-groups on o-cyclohexylphenol results in the formation of a much stronger pseudo acid that forms well-defined salts with inorganic bases, amines and heterocyclic bases.

The method of synthesis of this nitro-phenol has already been fully described.*

Method of Analysis.—In order to execute certain phases of this study, it was necessary to develop a satisfactory quantitative method of analysis for the compound. Of several methods considered, a colorimetric method employing a balancing type 40-millimeter colorimeter to compare unknowns with standards proved satisfactory and was adopted.

Since this compound is a dye, various concentrations in aqueous and in most organic solvents can be estimated with a reasonable degree of accuracy. In alkaline aqueous solutions the color is very intense and ranges from reddish orange in high concentrations to pale yellow in low concentrations. The color is known to be unchanged within a pH range of approximately 11 to 13. Therefore, in the preparation of aqueous solutions for analysis, the pH was adjusted within this range.

Standard solutions stored in air-tight glass containers for a period of 2 months were found to have decreased 2 per cent in concentration upon comparison with freshly prepared standards. Since this error is within the limits of accuracy of the method, it is not necessary to prepare fresh standards for shorter intervals than 2 months.

In order to determine the accuracy of the method, solutions known to be 2.0, 1.8, 1.6, 1.4, 1.2, 1.0, 0.8 and 0.6 times the concentrations of the standard were compared. The results showed that greatest accuracy was obtained when the two concentrations being compared were in the ratio of 3:2 or less. Under these conditions and with favorable illumination, the accuracy of the method was within an error of 2 per cent.

The method may be satisfactorily employed for analysis in solutions that have a natural color apart from that of the nitro-phenol compound, provided the natural color is not too predominant and that proper adjustments are made to the standard. However, when making determinations in petroleum oil–water spray mixtures, it is necessary to separate the oil from the water. This separation is accomplished by centrifuging and separating the two phases with a separatory funnel. Each solution is filtered before

* U. S. Patent No. 1,880,404. The compound was prepared by the Research Laboratories of The Dow Chemical Company, Midland, Mich

analysis in order to remove particles of emulsified oil and foreign material that may be present. True colloids, such as blood albumin, sodium caseinate and other emulsifying agents used in conventional amounts that cannot be readily separated from the water by this procedure do not seriously interfere with the determinations.

Solubility in Organic Solvents.—The solubility of dinitro-o-cyclohexylphenol in several common organic solvents was determined by employing the weighed residue method. These data are presented in table 1. The solubility was greater in the aromatic solvents than in the aliphatic solvents, which is due to the similarity of molecular structure between dinitro-o-cyclohexylphenol and the aromatic solvents.

Table 1.—Solubility of dinitro-o-cyclohexylphenol in various organic solvents.

Solvent*	Solubility of DN† in Grams per 100 Grams of Solvent			
	25° C	30° C	50° C	60° C
Acetic acid (glacial)	—	13.6	30.9	59.5
Acetone	—	39.6	—	—
Alcohol (ethyl 95%)	1.81	1.9	—	—
Benzene	47.97	109.0	185.0	262.0
Carbon tetrachloride	12.89	22.6	67.0	75.1
Ethyl acetate	30.63	45.3	—	—
Ethylene dichloride	37.87	64.1	123.1	—
Toluene	47.52	73.3	—	—
Xylene	43.52	72.5	125.7	207.0

* Technical grade materials were used.
† DN = Dinitro-o-cyclohexylphenol.

Solubility in Petroleum Spray Oils.—The solubility of dinitro-o-cyclohexylphenol in various petroleum oils that may be used for agricultural spray purposes was estimated by a colorimetric comparison of a diluted portion of the saturated solution with a standard. The general specifications of these oils, together with the solubility data, are presented in table 2. It is evident from the data in table 2 that the solubility of dinitro-o-cyclohexylphenol is appreciably different for each grade of oil.

Solubility in Water.—Although dinitro-o-cyclohexylphenol is almost insoluble in water, its aqueous solubility is an important factor affecting the efficiency of the compound in various spray combinations. The significance of this matter will be discussed in another section of the paper. Early in the study it became apparent that the solubility of the nitrophenol in water was related to the pH. Therefore, experiments were conducted to determine its solubility in waters of varying pH and at a temperature of 25 degrees C. The concentration of dinitro-o-cyclohexylphenol was determined according to the procedure described in another part of the paper.† The pH of the solution was determined by the glass electrode.

The results of these solubility determinations are graphically illustrated in fig. 1.

It is evident from the curve (fig. 1) that the compound becomes increasingly soluble with a rise in pH. The solubility

† See a preceding section, "Method of Analysis."

Table 2.—Solubility of dinitro-o-cyclohexylphenol in various grades of petroleum spray oils.

Approximate Specifications of Oils									Solubility of DN* in Grams Per 100 Grams of Oil		
Classification		Unsulfonatable Residue (Per Cent)	Distillation Range, Degrees F.				Viscosity Seconds Saybolt 100° F.	Specific Gravity 60° F.			
University of California Rating	Commercial Rating		Initial Boiling Point	10 Per Cent	10 Per Cent	90 Per Cent			0° C.	20° C.	30° C.
	Kerosene	95	345	389	426	474	30†	0.792	—	—	2.29
1	Light	90	538	566	610	669	60	0.896	—	2.04	3.71
2	Light-medium	92	532	568	625	695	65	0.896	—	—	3.20
3	Light-medium	92	546	573	633	706	70	0.896	—	—	2.85
4	Medium	92	559	597	646	716	80	0.899	—	—	2.34
5	Heavy	94	592	636	668	726	95	0.899	—	1.88	2.61
A	Dormant	71	564	622	658	715	110	0.938	8.60	9.25‡	16.00

* DN = dinitro-o-cyclohexylphenol. † Viscosity = thermal 385 seconds 50 degrees F. ‡ This determination made at 18 degrees C.

begins to increase very rapidly between a pH of 4 and 5.

Distribution of Dinitro-O-Cyclohexylphenol Between Oil and Water in Petroleum Oil Emulsions.—Dinitro-o-cyclohexylphenol can be used effectively in spray mixtures dissolved in a petroleum oil which is applied in the form of a quick-breaking emulsion. Since this compound is soluble in both petroleum oil and water, the amount initially contained in the oil phase of the emulsion becomes distributed between the oil and water. The ratio of this distribution depends upon the relative solubilities of the compound in each phase of the emulsion.

In view of the data already presented, which pertain to the relation of pH to the solubility of the compound in water, and in view of the fact that water used in spraying has a variable pH, a study of the phase distribution of the nitro-phenol in oil-water spray emulsions was undertaken.

Three grades of oil were used in these phase-distribution studies, in which the pH of the water was varied. Samples of these various emulsions were taken after completion of equilibrium, and the concentration of the nitro-phenol in the aqueous phase was determined colorimetrically. The concentration in the oil phase of the mixture was computed from the known total amount initially contained in the oil. The results obtained are presented in table 3.

It is evident from these data that the phase distribution of dinitro-o-cyclohexylphenol in petroleum oil–water emulsions is related principally to the pH of the water. High pH values are associated with higher percentages of the nitro-phenol in the aqueous phase, lower percentages in the oil phase and *vice versa;* in fact, over 95 per cent of the compound is contained in the oil phase when the pH of the aqueous phase is less than 5. The percentage of dinitro-o-cyclohexylphenol in the oil phase is greatly reduced with higher aqueous phase pH values.

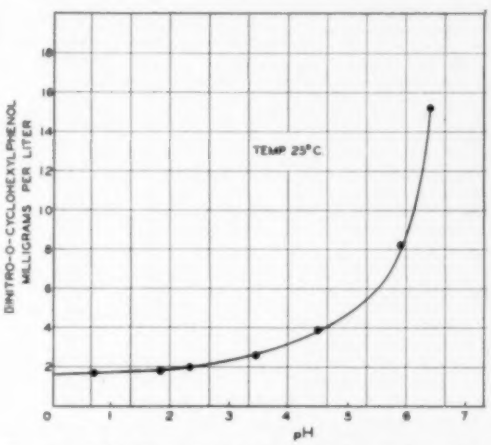


FIG. 1.—Solubility of dinitro-o-cyclohexylphenol in water at variable pH.

There are several factors that apparently lend a practical significance to the

Table 3.—Phase distribution of dinitro-o-cyclohexylphenol in petroleum oil spray emulsions.*

GRADE OF PETROLEUM OIL†	pH OF AQUEOUS PHASE	CONCENTRATION‡ OF OIL IN MIXTURE (PER CENT)	INITIAL CONCENTRATION OF DN** IN OIL SOLUTION (PER CENT)	PERCENTAGE OF TOTAL DN** IN OIL PHASE AT EQUILIBRIUM	PERCENTAGE OF TOTAL DN** IN AQUEOUS PHASE AT EQUILIBRIUM
Light-medium no. 3	3.0	2.0	1.0	99.9	0.1
	4.0	2.0	1.0	99.3	0.7
	4.2	0.5	0.6	95.6	4.4
	4.8	2.0	1.0	98.5	1.5
	5.0	2.0	1.0	97.3	2.7
	7.9	5.0	2.0	12.0	88.0
	8.4	0.5	1.4	12.1	87.9
Dormant	3.7	1.0	4.25	99.5	0.5
	4.1	1.0	4.25	99.9	0.1
	5.2	1.0	4.25	98.3	1.7
	8.3	0.7	4.25	27.0	73.0
	8.5	1.0	4.25	4.5	95.5
Kerosene	3.7	2.0	1.0	99.4	0.6
	4.7	2.0	1.0	96.8	3.2
	5.4	2.0	1.0	78.7	21.3

* Temperature about 25 degrees C.
† See table 2 for specifications.
‡ Per cent by volume.
** DN = dinitro-o-cyclohexylphenol.

distribution of dinitro-o-cyclohexylphenol between the oil and water phase of a spray mixture. One of the most important of these is the increased effectiveness of the nitro-phenol when it remains in the oil phase. This fact was evident from observations in various field tests and was demonstrated by laboratory spray experiments, with eggs of the citrus red mite, *Paratetranychus citri* (McG.). In these experiments very low dosages of both dinitro-o-cyclohexylphenol and oil were used in order to demonstrate whatever differences in efficiency existed between these several spray mixtures. The data obtained from the tests are presented in table 4. It is apparent in test *B*, in which 97.5 per cent of the dinitro-o-cyclohexylphenol existed in the oil phase, that the efficiency of the compound was considerably increased over test *A*, in which only 1.2 per cent of the nitro-phenol remained in the oil phase.

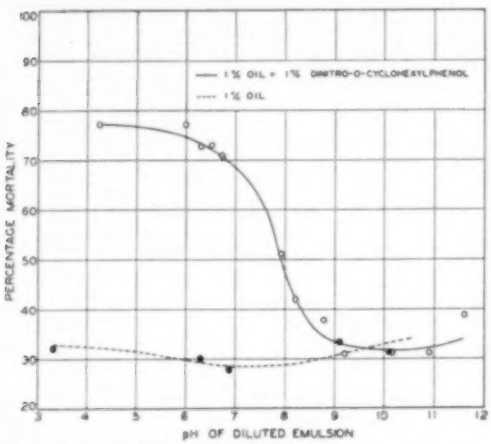


FIG. 2.—Relation of pH to the toxicity of dinitro-o-cyclohexylphenol–petroleum oil emulsions to the eggs of *Lygaeus kalmii* Stål.

The relation of pH to the toxicity of dinitro-o-cyclohexylphenol in petroleum oil–water spray mixtures has been demonstrated further in toxicity experiments with eggs of the plant bug, *Lygaeus kalmii* Stål.*

In these experiments the methods discussed in the paper by Kagy & Richardson (1936) were followed in detail. Oil-water spray mixtures were prepared with a dormant petroleum oil, a blood albumin emulsifier being used. The petroleum oil employed had the following specifications: specific gravity (20 degrees C.), 0.8815; sulfonation value, 82 per cent; viscosity (Saybolt 100 degrees F.), 99 to 100 seconds and (140 degrees F.) 53 to 54 seconds; boiling range, 606 degrees to 742 degrees F.

The pH values of the oil-water mixtures were determined electrometrically by means of the glass electrode. Adjustments of pH were accomplished by the addition of oxalic acid for low pH and sodium hydroxide for high pH.

The results of these experiments are presented in table 5, and the data are graphically represented in figs. 2 and 3, in which percentage mortality is plotted against pH of oil-water emulsion.

* This work was conducted by J. F. Kagy at Iowa State College under the direction of C. H. Richardson; N. P. Larson ably assisted in this phase of the investigation.

Table 4.—Relation of pH to the toxicity of dinitro-o-cyclohexylphenol–petroleum oil emulsions to the eggs of the citrus red mite, *Paratetranychus citri* (McG.).

Test No.	Materials and Concentrations*	Aqueous Phase of Spray Mixture		Approximate Per Cent of DN† in Oil Phase of Spray Mixture at Equilibrium	Number of Eggs	Number Dead	Percentage Mortality
		Nature of Water	Approximate pH				
A	DN,† 0.5% in light oil (no. 1)‡ at 0.25%**	Distilled+NH_4OH (28%) at 1–1300	10.6	1.2	395	242	61.3
B	DN,† 0.5% in light oil (no. 1) at 0.25%**	Distilled+CH_3CO-OH (glacial) at 1–800	3.3	97.5	325	253	77.8
C	Light oil (no. 1) at 0.25%**	Tap	7.9	0.0	272	147	54.0

* Concentration of dinitro-o-cyclohexylphenol given in per cent by weight of the oil.
† DN = dinitro-o-cyclohexylphenol.
‡ See table 2 for specifications.
** Blood albumin used at concentration of 1 ounce (in 3 parts of Fuller's earth) per 100 gallons of water.

Table 5.—Relation of pH to the toxicity of dinitro-o-cyclohexylphenol–petroleum oil* emulsions to the eggs of *Lygaeus kalmii* Stål.

MATERIALS AND CONCENTRATION	pH OF AQUEOUS PHASE	NUMBER OF EGGS	NUMBER DEAD†	PERCENTAGE MORTALITY
2.0 per cent oil containing 2.0 per cent DN‡ in solution	3.25	300	234	78.0
	3.45	300	238	79.3
	4.50	300	230	76.7
	4.93	300	236	78.7
	5.55	300	223	74.3
	5.82	300	233	77.7
	6.30	300	224	74.7
	6.57	300	202	67.3
	6.67	300	208	69.3
	6.85	300	203	67.8
	7.30	300	173	57.7
	8.00	300	166	55.3
	8.36	300	145	48.3
	9.22	300	121	40.3
	10.19	300	128	42.7
	10.60	300	123	41.0
	10.71	300	112	37.4
	10.75	300	128	42.7
	10.90	300	107	35.7
2.0 per cent oil	3.22	300	144	48.0
	4.11	300	142	47.3
	5.04	300	135	45.0
	6.52	300	126	42.0
	8.11	300	134	44.7
	9.85	250	113	45.2
	10.01	300	157	52.3
	10.30	300	137	45.7
	10.60	300	123	41.0
1.0 per cent oil containing 1.0 per cent DN‡ in solution	4.15	300	231	77.0
	5.97	300	229	76.5
	6.31	300	220	73.4
	6.50	300	218	72.7
	6.72	300	214	71.2
	7.89	300	153	51.0
	8.30	300	127	42.3
	8.80	300	110	36.6
	9.20	300	94	31.3
	10.17	300	95	31.6
	10.90	300	97	32.3
	11.60	300	118	39.3
1.0 per cent oil	3.44	250	80	32.0
	6.43	250	76	30.4
	6.94	250	70	28.0
	9.07	250	85	34.0
	10.07	250	81	32.4

* A dormant type of petroleum oil. For specifications see text.
† Includes embryos plus newly hatched nymphs.
‡ DN = dinitro-o-cyclohexylphenol.

These pH-toxicity curves for oil emulsions containing dinitro-o-cyclohexylphenol illustrate the following points: (1) For pH values of less than 6.0 there is little change in toxicity with respect to pH change. (2) From pH 6.0 to pH 9.0 there is a decided reduction in toxicity, with the greatest change occurring from pH 7.0 to pH 8.0. (3) For pH values greater than 9.0 there is little change in toxicity with respect to change in pH.

The toxicity curves for oil emulsions without dinitro-o-cyclohexylphenol illustrate the following points: (1) The toxicity under the conditions of this experiment remains practically constant. (2) At pH values greater than 9.0 the toxicity is about the same as the oil plus the nitrophenol in the same pH range.

It is apparent that the adjustment of these emulsions to high pH values results in an appreciable removal of the nitro-

phenol from the oil phase as a salt. It is also fairly well demonstrated that this shift in the equilibrium of the compound between the two phases decreases the toxicity of the emulsion.

In view of the foregoing laboratory evidence in regard to the relation between the toxicity of dinitro-o-cyclohexylphenol and the pH of spray waters, field studies

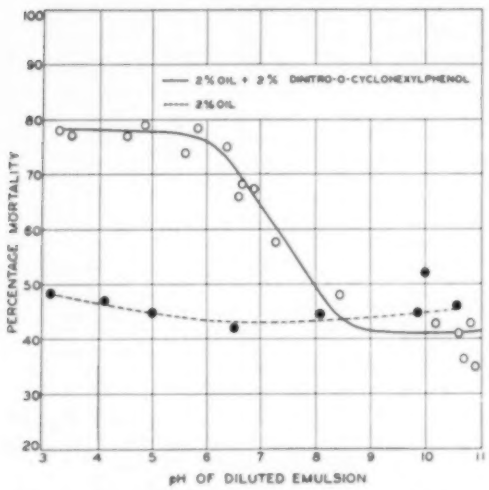


FIG. 3.—Relation of pH to the toxicity of dinitro-o-cyclohexylphenol–petroleum oil emulsions to the eggs of *Lygaeus kalmii* Stål.

were made on this phase of the problem. The pH of various waters used in field spraying was adjusted by the use of several organic and inorganic acids and buffers. Limited tests were conducted with oxalate, acetate and sulfate buffers, since these materials appeared to offer the most promise from the viewpoint of simplicity of practical field usage. However, after a consideration of the available analyses of waters used for spray purposes in various areas, the use of buffers does not seem economically practical. Rather the addition of a sufficient amount of a suitable acid to reduce the pH within a range of 3.5 to 5.0 is the most practical procedure from the standpoint of cost. Within this range of pH, practically all of the dinitro-o-cyclohexylphenol remains in the oil phase of the oil-water emulsion.

Of the various acids tested, oxalic acid at a concentration of 3 to 5 ounces per 100 gallons appears to be the most practical under field conditions.

The use of acidified spray waters has an important effect upon the performance of emulsifying and spreading agents that are likely to be most practical to use. Among materials that have been tested, at least in a preliminary way, are sulfated alcohols, sulfated fatty acids, sulfonated phenols, soaps, casein compounds, glyceryl oleate and blood albumin. According to present limited information, powdered blood albumin, used at the rate of from 1 to 1.25 ounces per 100 gallons, appears to be the most satisfactory material. In practice the blood albumin and oxalic acid are thoroughly mixed together dry and added to the water in the spray tank, after which the oil containing dinitro-o-cyclohexylphenol in solution is added. It is of considerable interest to note that, in acidified oil spray mixtures in which blood albumin is included, appreciably better wetting and spreading results and apparently higher deposits of oil are obtained than when blood albumin is used in alkaline or neutral spray mixtures.

The relation between pH and the effectiveness of petroleum oil–dinitro-o-cyclohexylphenol emulsions has received only limited consideration under field conditions. Early in this investigation it became evident that oil solutions of this compound, except at very low concentrations were too injurious to the foliage of citrus to offer much promise. Therefore, the study of oil–dinitro-o-cyclohexylphenol sprays was relegated to investigations on less phytocidal combinations of this compound.

It seems logical, however, that acidified oil spray emulsions in which practically all of the nitro-phenol remains in the oil phase should be more effective than basic oil emulsion sprays in which nearly all of the compound is contained in the water. In comparisons of alkaline and acidified oil–nitro-phenol spray emulsions of equal concentrations made by tree-tolerance tests on citrus, the acidified mixtures proved strikingly more toxic to the foliage. Furthermore, the foliage was more yellow after application, which indicated that greater quantities of the nitro-phenol were deposited with the acidic sprays than with the alkaline sprays.

Further studies should be made in regard to the application of this principle to dormant spray work. Some practical usage possibly could be made of this principle to increase the effectiveness of oil–nitro-phenol emulsions in dormant sprays

where phytocidal action is not such a serious consideration as it is in cases with trees in foliage.

FIELD EXPERIMENTS WITH DINITRO-O-CYCLOHEXYLPHENOL IN PETROLEUM OIL EMULSIONS.—Owing to the lack of information regarding the effect of dinitro-o-cyclohexylphenol in oil, on citrus and on certain other subtropical fruit trees under varied conditions, the field spray tests on these particular combinations have been very limited in extent. Consequently, the data thus far obtained relative to the effect of this compound on the trees, as well as upon the several species of insects involved, are preliminary.

Table 6.—Relative effectiveness of field spray treatments on the control of the black scale, *Saissetia oleae* (Bern.) on navel oranges.

PLOT NO.	CONCENTRATION* OF DN† (PER CENT)	CONCENTRATION OF OIL‡ (PER CENT)	NUMBER OF INSECTS	PERCENTAGE MORTALITY
22	0.50	0.50	1,175	96.9
24	1.00	0.50	1,420	97.3
26	2.00	0.50	1,917	98.6
23	1.00	0.25	943	91.9
25	2.00	0.25	1,957	92.1
28	—	0.50	460	80.4
27	—	0.25	812	73.3

* Concentration of dinitro-o-cyclohexylphenol is given in per cent by weight of the oil.
† DN = dinitro-o-cyclohexylphenol.
‡ Light-medium petroleum oil (no. 3). See table 2 for specifications. Blood albumin used at 1 ounce (in 3 ounces Fuller's earth) per 100 gallons of water.

For various reasons the minimum concentration of the lightest weight petroleum oil that will yield satisfactory results in insect and mite control on citrus is desirable. Therefore, in most of the tests on citrus, light-medium grades of oil* at arbitrary concentrations of 0.25 and 0.5 per cent have been used with varying concentrations of the nitro-phenol from 0.1 to 2.0 per cent in solution.

From field tests on orange trees, data involving the use of dinitro-o-cyclohexylphenol in control studies of the black scale, *Saissetia oleae* (Bern.), and the citricola scale, *Coccus pseudomagnoliarum* (Kuw.), together with the materials and concentrations used, are presented in tables 6 and 7.

The data in tables 6 and 7 indicate that relatively small amounts of dinitro-o-cyclohexylphenol afford an appreciably toxic effect on these two species of scale insects.

Limited field trials have been conducted with oil–nitro-phenol spray mixtures in control studies of the citrus red mite, *Paratetranychus citri*. Based on present incomplete information, the indications are that a spray mixture of the following composition will afford a satisfactory degree of control for this mite on citrus: 0.5 per cent dinitro-o-cyclohexylphenol dissolved in a light-medium oil (no. 3); 0.5 per cent of the oil plus the nitro-phenol is emulsified in the spray tank with 1.25 ounces of blood albumin, and 3 ounces of oxalic acid per 100 gallons of the various waters used in spraying this amount of acid adjusts the pH of the water phase within a range of 3.5 to 5.0. The tolerance of citrus trees to this particular mixture under varied conditions has not been fully determined.

A small experiment was conducted on the larvae of the citrus whitefly, *Dialeurodes citri* Ashm., in cooperation with D. B. Mackie and C. Gammon, of the California Department of Agriculture. Two concentrations of dinitro-o-cyclohexylphenol were used; that is, 1 per cent and 2 per cent dissolved in a light-medium oil (no. 2) in which stock mixtures were used at 0.5 per cent plus blood albumin.†

† One ounce of blood albumin + 3 ounces of Fuller's earth to 100 gallons of water.

Table 7.—Relative effectiveness of field spray treatments on the control of the citricola scale, *Coccus pseudomagnoliarum* (Kuw.) on navel oranges.

GROVE AND PLOT NO.	CONCENTRATION* of DN† (PER CENT)	CONCENTRATION‡ OF OIL** (PER CENT)	NUMBER OF INSECTS	PERCENTAGE MORTALITY
A-6	0.25	0.50	2,326	98.3
A-5	0.50	0.50	3,639	97.4
A-4	0.75	0.50	3,258	99.8
A-1	—	0.50	5,126	86.3
A-8	—	Untreated	5,162	76.0
B-2	0.50	0.50	7,908	98.5
B-1	—	1.67	3,217	99.9

* Concentration of dinitro-o-cyclohexylphenol is given in per cent by weight of the oil.
† DN = dinitro-o-cyclohexylphenol.
‡ Blood albumin used at 1.25 ounces + 3 ounces oxalic acid to 100 gallons of water in all spray mixtures except plot B-1, in which blood albumin at 1 ounce + 3 ounces Fuller's earth to 100 gallons of water was used.
** Light-medium petroleum oil (no. 3) was used in all plots except B-1, in which light petroleum oil (no. 1 was used. See table 2 for oil specifications.

* See table 2 for specifications.

The infestation of the whitefly was classed as light. The mortality from the treatment was 100 per cent in each instance. This may be compared with the regular treatment employed in the eradication of the whitefly, in which it has been found necessary to use a light-medium oil (no. 2) at 1.67 per cent to insure a 100 per cent mortality. In the tests the usual criteria for determining mortality of the larvae were evident 6 days after treatment, whereas, in the case of the regular oil spray, a period of 14 days or longer must elapse after treatment before the mortality count can be made.

In an experiment on the control of the European elm scale, *Gossyparia spuria* (Mod.), Mackie & Carter‡ have compared the dormant tank mix oil emulsions (Borden 1934) with the same concentrations of similar oil containing 4 per cent and 6 per cent dinitro-o-cyclohexylphenol. Excellent control was obtained with oil concentrations from 2 per cent to 4 per cent containing 4 per cent of the nitrophenol dissolved in the oil phase. With the same concentrations of a similar dormant oil emulsion without the nitrophenol, the mortalities ranged from 19 per cent to 73 per cent. In this experiment the increased effectiveness of oils was strikingly demonstrated by the inclusion of dinitro-o-cyclohexylphenol.

It is of interest to note that Kagy & Richardson (1936) found in laboratory experiments that dinitro-o-cyclohexylphenol in oil solutions was very effective for the control of the European elm scale.

In field control studies of the red scale, *Aonidiella aurantii* (Mask.), spray mixtures of dinitro-o-cyclohexylphenol have shown that the compound is of little value at concentrations that result in important foliage and fruit injury. However, it is of interest to note that in replicated laboratory tests with the red scale, Ebeling* has shown an increase in the toxicity of oil† through the incorporation of the nitrophenol. In these tests, lemons that were infested with red scale were sprayed in the laboratory with diluted oil emulsions containing 1 per cent and 1.5 per cent oil. The oil employed in these tests was a light-medium (no. 3) grade. The nitrophenol was used at a concentration of 1 per cent in the oil.

The results of these tests are summarized in table 8.

Table 8.—Toxicity of dinitro-o-cyclohexylphenol in petroleum oil to the red scale, *Aonidiella aurantii* (Mask.), in the laboratory.

Oil* Concentration (Per Cent)	DN† Concentration (Per Cent)	Number of Insects	Net Percentage Mortality
1.0	—	8,829	64.2
1.0	1	10,140	81.3
1.5	—	9,401	82.9
1.5	1	9,778	88.9

* Light-medium petroleum oil (no. 3). See table 2 for specification. Concentration of oil given in per cent by volume of spray mixture.

† DN = dinitro-o-cyclohexylphenol. Concentration given in per cent by weight of the oil.

This is apparently the first quantitative evidence showing that the toxicity of an oil to the red scale has been increased by the addition of a solute. It is of interest to note that Smith (1932a), in similar experiments, was unsuccessful in increasing the toxicity of petroleum oils to the red scale by the addition of various organic compounds, which included some of the most toxic of insecticides.

Several preliminary field experiments were conducted in which the nitro-phenol was applied during the dormant season for the control of the walnut scale, *Aspidiotus juglans-regiae* Comst., and the frosted scale, *Lecanium pruinosum* Coq., on Persian walnuts and also for the control of the black scale, *Saissetia oleae* (Bern.), on apricot. The results obtained from these tests, together with the materials and concentrations used, are presented in table 9.

The data in table 9 indicate that dinitro-o-cyclohexylphenol is appreciably toxic to each of these three species of insects. In connection with the tests on apricot trees, it was of interest to note that all trees in plot C-2 blossomed, set fruit and leafed out approximately 3 weeks earlier than any other trees in this particular orchard. Therefore, the circumstances indicated that this nitrophenol exerted an influence upon the termination of dormancy. In subtropical areas the prolonged dormancy of certain

‡ Mackie, D. B., and W. B. Carter. Experiments on the control of the European elm scale. Unpublished data on file in the California State Department of Agriculture, Division of Entomology, Sacramento, Calif.

* Ebeling, W. Laboratory experiments on the red scale. Unpublished data on file at the Citrus Experiment Station, Riverside, Calif.

† The term "increasing the toxicity of oil" has been used for convenience by some authors, although it is possible that the inclusion of toxic solutes does not alter the toxicity of the oil itself.

deciduous fruit trees is an important horticultural problem in certain seasons, and the possible relation of dinitro-o-cyclohexylphenol to this problem is being investigated by horticulturists.

EFFECT OF OIL SOLUTIONS OF DINITRO-O-CYCLOHEXYLPHENOL ON CITRUS.—Repeated tree-tolerance tests on both lemons and oranges have shown that 0.25 per cent of the nitro-phenol in solution in no. 3 oil used at a concentration of 0.5 per cent according to the tank-mix method (Smith 1932b) may be employed with apparent safety even to the tenderest new foliage and fruits. Slight to moderate injury to the new foliage has occurred when the amount of dinitro-o-cyclohexylphenol in oil solution was increased from 0.25 to 0.5 per cent; and when the amount was further increased to 1.0 per cent, serious injury occurred.

It was concluded that in the use of oil emulsions containing dinitro-o-cyclohexylphenol, the margin of safety between the concentration of the compound in oil required for a satisfactory control and that which causes an important degree of injury was so narrow that further study of the mixtures on citrus did not appear warranted.

In connection with one particular series of spray tests, it was strikingly demonstrated that high temperature (above 100 degrees F.) and low relative humidity (below 25 per cent) at the time of application and continuing for several days thereafter increased foliage and fruit injury.

EXPERIMENTS WITH DINITRO-O-CYCLOHEXYLPHENOL IN ORGANIC SOLVENTS OTHER THAN OIL.—Dinitro-o-cyclohexylphenol, when used in dust mixtures with walnut-shell flour and redwood-bark flour, has afforded good control of certain insects and mites,* and can be safely employed on citrus. Since the nitro-phenol exists in a crystalline state in these dust mixtures, an attempt was made to prepare sprays less phytocidal than oil solutions by the use of this compound in a manner to secure crystalline deposits on the tree. The most practical method of depositing crystalline dinitro-o-cyclohexylphenol consists of dissolving the compound in a suitable solvent which is applied in the form of a diluted spray emulsion. A solvent that has a sufficiently low boiling point and high vapor pressure escapes from the tree in a reasonable length of time and leaves as a residue

Table 9.—Relative effectiveness of certain field spray treatments applied during the dormant season for the control of three species of scale insects.

SPECIES OF SCALE INSECT AND HOST	GROVE AND PLOT NO.	MATERIALS* AND CONCENTRATIONS†	NUMBER OF INSECTS	PERCENTAGE MORTALITY
Walnut scale, *Aspidiotus juglans-regiae* Comst., on Persian walnuts	A-3	DN,‡ 2.0% in heavy petroleum oil (no. 5),** 1.5%	1,849	73.7
	A-4	Heavy petroleum oil (no. 5), 1.5%	2,412	65.8
	A-1	DN,‡ 2.0% in heavy petroleum oil (no. 5), 3.0%	2,168	95.8
	A-2	Heavy petroleum oil (no. 5), 3.0%	2,392	82.0
	A-6	(No treatment)	2,560	35.7
Frosted scale, *Lecanium pruinosum* Coq., on Persian walnuts	B-1	DN,‡ 0.5% in No. C-6 oil,*** 1.0%	1,182	98.6
	B-2	Dormant petroleum oil,** 1.5%	1,567	99.0
	B-3	(No treatment)	1,300	79.5
Black scale, *Saissetia oleae* (Bern.), on apricot	C-1	DN,‡ 3.0% in dormant petroleum oil, 1.0%	1,017	99.9
	C-2	DN,‡ 3.0% in dormant petroleum oil, 2.0%	1,125	100.0
	C-3	Dormant petroleum oil, 2.0%	1,494	98.7
	C-4	Distillate oil,†† 2.5%+caustic soda, 0.31%	1,481	50.9

* Blood albumin used at 1 ounce +3 ounces Fuller's earth per 100 gallons of water in all spray mixtures except B-1 and C-4.
† Concentration of dinitro-o-cyclohexylphenol given in per cent by weight of oil. Concentration of oil given in per cent by volume of spray mixture.
‡ DN = dinitro-o-cyclohexylphenol.
** See table 2 for oil specifications.
*** An experimental material prepared by The Dow Chemical Company. General specifications of the oil are: unsulfonatable residue 78 per cent, viscosity 80–85 seconds Saybolt, distillation range 238–405 degrees C.
†† An unrefined, low-viscosity petroleum oil commonly used for orchard heating purposes.

* See a later section of this article, "Experiments with Dinitro-O-Cyclohexylphenol in Dust Mixtures."

the crystalline dinitro-o-cyclohexylphenol. The qualifications of the solvent demand that it have an extremely low water solubility; otherwise upon addition to the spray tank precipitation of the nitrophenol would result. Preliminary tests showed that a solution of the compound in such solvents as toluene, benzene and carbon tetrachloride could be satisfactorily dispersed in water by the tank-mixture method.

A number of laboratory toxicity experiments were conducted with solutions of dinitro-o-cyclohexylphenol in different solvents applied to immature black scale reared on potato sprouts and small oleander plants. The nitro-phenol was dissolved in a given solvent at a concentration of 20 per cent, and the solution was applied as an emulsion at a concentration of 0.25 per cent, with an acidified blood albumin emulsifying agent. The diluted spray under these conditions contained about 0.05 per cent dinitro-o-cyclohexyl phenol. In all instances the compound was appreciably toxic to immature black scales that were of a size usually considered to be too large to control satisfactorily under field conditions. In these experiments the factor of toxicity to the insect did not appear to be of so much importance as possible phytocidal action with reference to citrus. Citrus trees, including lemons, grapefruit, and Valencia and Washington Navel oranges, were sprayed with dinitro-o-cyclohexylphenol in the following solvents (concentrations used were as given above): o-dichlorobenzene (B.P., 179.0 degrees C.); toluene (B.P., 111.0 degrees C.); benzene (B.P., 80.4 degrees C.); carbon tetrachloride (B.P., 78.0 degrees C.).

The trees were sprayed in early summer when there was an abundance of new growth and immature fruit. The temperature at the time of treatment was between 96 degrees and 100 degrees F. The o-dichlorobenzene solution of dinitro-o-cyclohexylphenol, which had the highest boiling point and the lowest vapor pressure of those solvents tested, gave the most severe injury. The tender, new growth was entirely burned and there was considerable fruit spotting. There was no apparent injury to old leaves, although some leaf-drop followed a few weeks after treatment. The injury with the toluene solution was less severe, and there was only negligible injury with benzene and carbon tetrachloride solutions.

Repeated tolerance experiments with the group of solutions established a positive correlation between the boiling point of the solvent and degree of injury to citrus. Also, a reduction in quantity of solvent to that amount necessary to maintain a nearly saturated solution of the compound resulted in a considerable reduction of injury with the higher boiling-point solvents.

Although the use of dinitro-o-cyclohexylphenol on citrus in solvents that have a low boiling point (100 degrees C. or less) offers considerable promise, the information regarding insecticidal value and tree reaction of these mixtures is too limited to warrant definite conclusions.

EXPERIMENTS WITH AQUEOUS DISPERSIONS OF DINITRO-O-CYCLOHEXYLPHENOL.—The early toxicological work with dinitro-o-cyclohexylphenol* consisted of testing solutions of its sodium and nicotine salts as contact insecticides on the melon aphid, *Aphis gossypii* Glov. It was concluded that the salts of the compound were toxic to this insect. Owing to the fact that at this time dinitro-o-cyclohexylphenol was of only theoretical interest, further work with aqueous solutions of the compound was temporarily discontinued.

The toxicity of aqueous sprays of dinitro-o-cyclohexylphenol was recognized early in the present studies. In certain experiments the ammonium salt of the nitro-phenol was tested in the laboratory on the eggs of the citrus red mite, *Paratetranychus citri*.† An aqueous solution of the ammonium salt at a concentration of 0.00125 per cent was found to be toxic to eggs of this mite. It was further evident from the previously described experiment on the effect of pH on the toxicity of oil–dinitro-o-cyclohexylphenol emulsions that aqueous solutions of this compound were very toxic to mite eggs. In table 4, a comparison of tests *A* and *B* illustrate this principle. In test *B*, in which 97.5 per cent of the nitro-phenol remained in the oil phase of the emulsion, there was 77.8 per cent mortality. In test *A*, in which only 1.2 per cent of the

* Kagy, J. F. Unpublished report of the Crop Protection Institute, on file Durham, N. H. 1931.

† Boyce, A. M., C. O. Persing and D. T. Prendergast. Laboratory studies on the eggs of the citrus red mite, *Paratetranychus citri* (McG.). Unpublished data on file at the Citrus Experiment Station, Riverside, Calif. 1936.

compound remained in the oil phase, the mortality was 61.3 per cent. The high mortality in test *B* cannot be logically attributed to the nitro-phenol in oil solution, so that an appreciable mortality must have been exercised by the dinitro-o-cyclohexylphenol in the aqueous phase in which it existed in the form of the ammonium salt.

In laboratory experiments with the California red scale, *Aonidiella aurantii* (Mask.), Ebeling‡ has shown that water solutions of the sodium salt of dinitro-o-cyclohexylphenol were toxic to this insect. In this work it was found that a proprietary product, *Vatsol OT*,** was an effective wetting and spreading agent for carrying the nitro-phenol under the armor to the body of the scale insect. Because the dosages were beyond the limit of tree tolerance, the experiments were considered to be of theoretical interest only.

In the summer season of 1937, an investigation* was begun which was concerned with methods for evaluating the control of black scale on citrus under field conditions. Throughout the course of this work a number of experiments with aqueous solutions of dinitro-o-cyclohexylphenol were included.

The results of two of these field experiments with aqueous solutions of dinitro-o-cyclohexylphenol are summarized in table 10. In this experiment the results were evaluated by a post-treatment mortality count of scale insects on 40 leaves selected at random from the north side of the tree. More recently, however, this method of evaluation has been found to be inadequate for detecting small differences between the effectiveness of treatments, so that the small differences in table 10 are probably not significant. However, it can be conservatively concluded that those sprays containing the sodium salt at a concentration of 0.05 per cent or greater are at least as effective as the oil sprays.

Table 10.—Results of field tests on citrus with aqueous solutions of the sodium salt of dinitro-o-cyclohexylphenol on the black scale, *Saissetia oleae* (Bern.).

GROVE AND PLOT	MATERIALS AND CONCENTRATION*	NUMBER OF INSECTS	PERCENTAGE† SURVIVAL
A-1	Na DN,‡ 0.05% in acetone, 0.30%+*Vatsol OT*,** 0.03%	2,988	0.20
A-2	Na DN,‡ 0.01% in acetone, 0.60%+*Vatsol OT*,** 0.03%	1,872	0.59
A-3	*Vatsol OT*,** 0.03%	2,237	43.54
A-4	Light-medium petroleum oil (no. 3),*** 1.5%††	1,954	6.55
B-1	Na DN,‡ 0.025% (in 3 parts of diatomaceous earth)+potassium caseinate spreader, 0.125%	1,757	4.10
B-2	Na DN,‡ 0.025%+ammonium caseinate, 0.0234%	1,063	3.66
B-3	Na DN,‡ 0.05% (in 3 parts of diatomaceous earth)+ammonium caseinate, 0.0234%	8,124	0.57
B-4	Na DN,‡ 0.025% (in 3 parts of diatomaceous earth)+*Vatsol OT*, 0.02%	12,211	4.01
B-5	Light-medium emulsive oil (no. 3),††† 1.25%	1,555	1.29

* Concentrations of materials other than oil are given in per cent by weight of total spray mixture.
† Percentage survival calculated from the number of dead and live scale insects 30 days after treatment.
‡ Na DN = sodium salt of dinitro-o-cyclohexylphenol.
** A proprietary emulsifying agent consisting of the sodium salt of an alkyl ester of sulfosuccinic acid.
*** See table 2 for specifications.
†† Prepared according to the tank-mixture method, using 1.25 ounces blood albumin+4 ounces oxalic acid per 100 gallons of water.
††† A petroleum oil containing 1 per cent glyceryl mono oleate. For other specifications see table 2.

It was later determined that a percentage survival value, based on an estimate of the live scale population densities before and after treatment, considerably decreased the error of evaluation. This method was facilitated by a fixation process† of the live scale insects which permitted a more rapid and a more nearly accurate distinction to be drawn between the dead and live scale insects.

It should be pointed out that the percentage survival value based upon the live scale before and after treatment yields a higher percentage survival value than survival percentages based on single

‡ Ebeling, W. The role of physical and chemical factors in the performance of spray liquids. Unpublished manuscript on file at the Citrus Experiment Station, Riverside, Calif. 1938.

** *Vatsol OT* is a proprietary wetting agent consisting of the sodium salt of an alkyl ester of sulfosuccinic acid, per manufacturer.

* Investigation conducted in cooperation with K. E. Maxwell and J. P. La Due.

† Kagy, J. F., C. O. Persing and K. E. Maxwell. A fixation method for distinguishing between dead and live black scale on citrus. Manuscript in press.

post-treatment mortality counts. This difference is due to the inclusion of the natural mortality prior to treatment in the case of single post-treatment mortality counts.

Results of a more comprehensive field experiment are summarized in table 11.

Table 11.—Relative effectiveness of the sodium salt of dinitro-o-cyclohexylphenol in aqueous field sprays on the control of the black scale, *Saissetia oleae* (Bern.).

Replicate No.	Na DN* 0.035 Per Cent			Standard Treatment: Light-Medium Petroleum Oil (No. 3)† 1.67 Per Cent +Blood Albumin 0.25 Pound Per 100 Gallons of Water		
	Number of Live Insects on 200 Leaves From Four Trees		Percentage Survival‡	Number of Live Insects on 200 Leaves From Four Trees		Percentage Survival
	Before Treatment	After Treatment		Before Treatment	After Treatment	
1	5,087	2	0.04	5,658	28	0.49
2	7,921	10	0.13	7,714	13	0.17
3	9,887	7	0.07	4,156	14	0.34
4	9,019	5	0.06	10,230	97	0.95
5	8,106	12	0.15	5,891	11	0.19
Total	40,020	36	0.09	33,649	163	0.49

* Na DN = sodium salt of dinitro-o-cyclohexylphenol. This compound was dissolved in 2 quarts acetone per 100 gallons of water containing 0.025 per cent *Vatsol OT*.

† See table 2 for specifications.

‡ Percentage survival calculated by dividing the number of live scale present on 200 leaves 30 days after treatment by the number of live scale present on 200 leaves 1 day prior to treatment.

In this experiment the effectiveness of the sodium salt of dinitro-o-cyclohexylphenol was compared with a conventional oil treatment in five replicated plots. The sample unit from each plot consisted of 50 leaves selected at random from the north quadrant of four trees.

The data in table 11 illustrate that the percentage reduction of live scale insect populations was about the same for each treatment. Although mathematically there is a significant difference between the effectiveness of the two treatments, the results may be considered as identical from a practical point of view.

It may be concluded that an aqueous solution of the sodium salt of dinitro-o-cyclohexylphenol employed at a concentration of 0.035 per cent gave satisfactory commercial control in this experiment.

The sodium salt of dinitro-o-cyclohexylphenol has several disadvantages. This salt, although completely soluble in water at the dosages employed, does not go into solution very rapidly when added directly to the tank. In fact, within the interval of time required to empty a 400-gallon spray tank, which is about 20 minutes, the salt does not entirely go into solution and as a result much of it remains in suspension. Different methods of dispersing the salt rapidly were tried. One method consisted of dissolving the salt in acetone prior to its incorporation in the spray tank. This procedure improved the degree of solutions but was found to be impractical. Furthermore, it was not entirely satisfactory, owing to the fact that dilution of the acetone solution resulted in a rapid crystallization of the salt.

The most practical method employed for dispersing the sodium salt of dinitro-o-cyclohexylphenol consists of preparing the salt in the spray tank, which is accomplished by the following procedure: A solution of the nitro-phenol is prepared, with a minimum amount of a low-boiling-point and water-insoluble solvent such as benzene. This solution is added to the water in the spray tank after the addition of the wetting agent and an amount of sodium hydroxide or a commercial grade of caustic soda chemically equivalent to the nitro-phenol. In this manner an emulsion of this solution in water is formed, and the nitro-phenol is removed from the organic solvent to the aqueous phase by the formation of the water-soluble sodium salt.

Aqueous solutions tend to foam much more than do oil emulsion sprays, and the

agitation produced by spray equipment designed for tank-mix oil emulsions is too violent for satisfactory results with these aqueous sprays. More important still is the fact that atmospheric carbon dioxide, when beaten into the spray liquid, reacts with the salt of dinitro-o-cyclohexylphenol with the resultant formation of sodium carbonate and free phenol. This free phenol passes out of solution by a flotation process. Excessive agitation may be remedied by disconnecting one or more of the agitator paddles.

The crystalline state and limited solubility of the sodium salt and the complications that result from its use were found to be disadvantages. An attempt was therefore made to prepare a salt of the nitro-phenol that would possess greater water solubility than the sodium salt. The inorganic salts of dinitro-o-cyclohexylphenol are crystalline solids almost without exception, and all are sparingly soluble in water. Organic salts that have been prepared to date, with one exception, have been crystalline and more sparingly soluble than the sodium salt. The triethanolamine salt of dinitro-o-cyclohexylphenol is unique in that it is semi-solid and noncrystalline. Also this salt was found to be water-soluble in all proportions. The salt is easily prepared by boiling the nitro-phenol in a water solution of triethanolamine.

Commercial triethanolamine is a mixture containing approximately 82.5 per cent triethanolamine, 15 per cent diethanolamine and 2.5 per cent monoethanolamine. Consequently, a reaction of this material with dinitro-o-cyclohexylphenol results in the formation of a mixture of the three salts. For convenience this mixture is referred to as the triethanolamine salt. In preparations of concentrated solutions of the salt for field usage it was found necessary to employ an excess of the amine above that amount chemically equivalent to the nitro-phenol. This excess prevented on partial dilution a precipitation of the less soluble salts and imparted to the solution the property of water miscibility in all proportions. A concentrated solution of the triethanolamine salt can be added directly to the spray tank without the physical difficulties encountered with the sodium salt.

Several preliminary field trials with the triethanolamine salt of dinitro-o-cyclohexylphenol indicated that it could be employed safely on citrus and offered promise in controlling the black scale. In view of the promising results obtained in these preliminary tests, a more extensive field experiment was conducted. In this experiment relative effectiveness of this salt was compared with a conventional oil treatment in four replicated plots. Forty leaves selected at random from the north quadrant of each tree constituted the sample unit. Effectiveness was evaluated by a percentage survival based upon mortality counts before and after treatment. The results of these experiments are presented in table 12.

In this experiment the percentage survival was higher than in previously described experiments on this insect. The greater survival was due probably to the fact that the experiment was conducted in an area where the black scale insects were more mature and inherently more resistant to insecticidal treatments than in the previous cases.

In this experiment the triethanolamine salt of the nitro-phenol afforded a degree of control slightly inferior to that of the standard treatment. The wetting agent used in this experiment was blood albumin at a concentration of 4 ounces per 100 gallons of water. The fact that this wetting agent is known to be less efficient than *Vatsol OT*, which was used in a previous experiment with the sodium salt of the nitro-phenol, may have contributed to the slightly inferior results obtained with the triethanolamine salt. However, it may be concluded that the aqueous solution of the triethanolamine salt of this compound affords a control of the black scale, practically equal to that of a conventional oil spray.

Experiments with colloidal suspensions of dinitro-o-cyclohexylphenol have afforded promising results in control of the black scale, *Saissetia oleae*, and the citrus red mite, *Paratetranychus citri*, on citrus. These colloidal suspensions may be prepared in several ways. However, those used principally have been prepared either by precipitating the parent compound from a solution of one of its salts or from a dispersion of the so-called bentonite fusion mixture by the addition of acid to the spray water. This bentonite fusion mixture is prepared by mixing 50 parts of bentonite with 50 parts of the

Table 12.—Relative effectiveness of the triethanolamine salt of dinitro-o-cyclohexylphenol in aqueous field sprays on the control of the black scale, *Saissetia oleae* (Bern.).

Replicate No.	R_3N DN* (0.035 Per Cent DN) + Blood Albumin 0.25 Pounds per 100 Gallons of Water			Standard Treatment: Light-Medium Petroleum Oil (No. 3)† 1.67 Per Cent + Blood Albumin 0.25 Pound Per 100 Gallons of Water		
	Number of Live Insects on 160 Leaves From Four Trees		Percentage Survival‡	Number of Live Insects on 160 Leaves From Four Trees		Percentage Survival‡
	Before Treatment	After Treatment		Before Treatment	After Treatment	
1	4,022	51	1.27	2,955	47	1.59
2	4,192	68	1.62	4,925	36	0.73
3	2,844	141	4.96	5,588	88	1.57
4	7,257	169	2.33	3,763	50	1.33
Total	18,315	429	2.34	17,231	221	1.28

* R_3N DN = Triethanolamine salt of dinitro-o-cyclohexylphenol − (0.035 per cent dinitro-o-cyclohexylphenol + 0.024 per cent commercial triethanolamine).
† See table 2 for specifications.
‡ Percentage survival calculated by dividing the number of live scale on 160 leaves 30 days after treatment by the number of live scale on 160 leaves 1 day prior to treatment.

molten nitro-phenol maintained at a temperature slightly above the melting point of the compound. The molten mixture is allowed to cool and the resultant brittle cake is ground to a powder.

When bentonite is mixed with molten dinitro-o-cyclohexylphenol the compound is readily absorbed by the clay where it reacts to form a mixture of salts. Dispersions of the fusion mixture in tap water are alkaline in reaction (pH 7.5 to 8.0). In this range of pH all of the nitrophenol initially absorbed by the bentonite is present in the system as salts which are in solution in the aqueous phase. Comparisons of the lethal effectiveness of different dispersions of the fusion mixture with a true solution of the triethanolamine salt to eggs of the citrus red mite were made. In certain instances oxalic acid, used to precipitate the parent compound, was added to the water prior to the addition of the nitro-phenol, and in other instances the acid was added afterward.

On the basis of an equivalent amount of dinitro-o-cyclohexylphenol, a solution of the soluble inorganic salts present in the basic aqueous phase of a dispersion of the bentonite fusion mixture was as toxic as a solution of the triethanolamine salt. The acidic dispersion, prepared by suspending the fusion mixture in water that had been previously acidified with oxalic acid, was significantly more effective than either the basic dispersion of the bentonite fusion mixture or the solution of the triethanolamine salt. The acidic dispersion prepared by acidifying the basic dispersion of the bentonite fusion mixture was even more effective than the acidic dispersion prepared by adding the bentonite fusion mixture to acidified water. Thus it appears that the most effective method of using the fusion mixture is to suspend it in the spray water, which is usually basic, thereby allowing the salts of the nitro-phenol to become dissolved in the water, and then to add acid to precipitate the parent phenol.

Colloidal dispersions of dinitro-o-cyclohexylphenol applied in laboratory experiments to immature black scale on citrus have resulted in very high mortalities.

Although most of the field work with aqueous dispersions of dinitro-o-cyclohexylphenol has been confined to the control of the black scale, preliminary work on the control of the citrus red mite has been conducted. While definite conclusions are not warranted on the possible value of these sprays in this regard, promising results have been obtained.

The problem of injury to citrus trees resulting from the application of aqueous solutions of dinitro-o-cyclohexylphenol has received considerable attention. Over a 2-year period, aqueous solutions containing as high as 0.05 per cent dinitro-o-cyclohexylphenol have been applied to citrus with comparative safety. From slight to moderate injury to tender new

growth has resulted but this injury is considered to be only negligible. High temperatures (above 95 degrees F.) accentuate the degree of injury to some extent. A unique type of fruit "spotting," which appears to be of minor importance, has been encountered in connection with these particular spray solutions. Although considerable progress has been made in reducing the degree of this "spotting" it has not been eliminated. Studies in this regard are in progress.

It may be of interest to point out that with possibly one exception none of the major scale insect pests of citrus at the present time is successfully controlled with nonoil sprays. Although the results with aqueous sprays that contain salts of dinitro-o-cyclohexylphenol have been very encouraging, an extensive amount of laboratory and field experimentation is necessary in order to determine fully the merits and limitations of these materials. Further work with aqueous sprays of salts of the nitro-phenol is in progress and results on the control of black scale and citrus red mite will be forthcoming.

EXPERIMENTS WITH DINITRO-O-CYCLOHEXYLPHENOL IN DUST MIXTURES.—This phase of the work has received considerable attention since it was early evident that dust mixtures of the nitrophenol are very toxic to the citrus red mite. Since these studies, particularly with reference to the control of certain mites on citrus and Persian walnuts,* are reported in detail in another paper, only a few of the more important points will be discussed here.

Various kinds of mixtures have been prepared in an effort to obtain a satisfactory dust of this compound. The most satisfactory procedure for preparing the dust consists of spraying a toluene solution of the nitro-phenol on to a suitable diluent. A specially constructed mixing device insures a fairly homogeneous distribution of the solvent in the diluent. As the solvent evaporates, the crystalline dinitro-o-cyclohexylphenol is uniformly dispersed in the diluent.

Several common diluents, including lime, talc, bentonite and certain diatomaceous earths, were found to react with the nitro-phenol, forming salts. These dust mixtures were found to be less satisfactory than equivalent mixtures of the compound in relatively more inert diluents. Therefore the study was confined to dust mixtures with less reactive diluents, such as lignocellulosic materials. Of these, walnut-shell flour and redwood-bark flour were found to be the most satisfactory from the standpoint of physical properties, availability and cost.

Based on results obtained in the laboratory and in the field there developed a demand on the part of the growers for this material in their control program of the citrus red mite.

A proprietary product registered in California as *DN-Dust* was made available for limited commercial usage in April, 1938. This product contains approximately 1 per cent dinitro-o-cyclohexylphenol with walnut-shell flour as a diluent. Several thousands of acres of citrus have been treated for control of the citrus red mite, and results obtained have been generally satisfactory.

Field studies with dinitro-o-cyclohexylphenol dust mixtures in relation to the control of the common red spider, *Tetranychus telarius*, on Persian walnuts have shown that the material will afford satisfactory results.

In the application of this dust mixture on citrus and Persian walnuts it was early evident that a more thorough coverage is necessary than can be accomplished with conventional dusting equipment. Consequently, a study of dusting equipment was undertaken in cooperation with the Division of Agricultural Engineering of the University of California. This investigation has resulted in the development of improved equipment, and many dusting units have recently been constructed.

Field studies with dinitro-o-cyclohexylphenol dust mixtures in relation to control of the citrus thrips,* *Scirtothrips citri* (Moult.), have shown that a high degree of mortality occurs initially. The duration of the residual action is very short, and for this reason it is unlikely that the nitrophenol dust alone would afford satisfactory results. However, preliminary results on navel oranges with sulfur incorporated in the dinitro-o-cyclohexylphenol dust mixture indicate that the degree of con-

* Boyce, A. M., D. T. Prendergast, J. F. Kagy and J. W. Hansen. Dinitro-o-cyclohexylphenol in the control of mites on citrus and Persian walnuts, published in this number.

* Investigations conducted in cooperation with R. S. Woglum and H. C. Lewis, entomologists of the California Fruit Growers Exchange.

trol obtainable with this combination may be superior to that with sulfur alone.

In experiments pertaining to control of the greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), on Valencia oranges, certain laboratory and field tests were conducted with a dust mixture composed of 1 per cent dinitro-o-cyclohexylphenol incorporated with walnut-shell flour. This dust mixture was found to be very toxic to the insect.

In several limited laboratory experiments with dinitro-o-cyclohexylphenol, the effectiveness of dust mixtures on the larvae (second instar) of the orange tortrix, *Argyrotaenia citrana* (Fern.), was considered. Both the parent compound and the calcium salt were found to be toxic to this insect at relatively low concentrations.

Dinitro-o-cyclohexylphenol has been used in dusts and sprays in several field tests dealing with nymphs and adults of the green citrus aphid, *Aphis spiraecola* Patch, and the melon aphid, *Aphis gossypii*, on citrus. Although a fairly high degree of mortality of aphids occurred in certain of these tests, in no instance was satisfactory control obtained.

Field trials are in progress in which dust mixtures containing 1 per cent dinitro-o-cyclohexylphenol with walnut-shell flour and also with redwood-bark flour as diluents are employed in the control of the black scale and the citricola scale on oranges. The newly hatched larvae of both of these insects are readily killed by the dust when they walk through fresh deposits. Laboratory and field evidence indicates that the nitrophenol dust will kill these larvae for a period of approximately 14 days after they "settle down" on the leaves. However, owing to the extended period of hatching, which necessitates carefully timed, multiple treatments, it is unlikely that these dust mixtures would be practical to rely upon solely in the control of these two scale insects although they may prove useful as a supplement to the conventional control measures in certain instances.

RELATION OF DINITRO-O-CYCLOHEXYLPHENOL TO PUBLIC HEALTH.*—Heymans & Casier (1935) reported that 2-4-dinitro-6-cyclohexylphenol was lethal for pigeons in a single intravenous dosage of 7 milligrams per kilogram of body weight. The low dosages produced vomiting, while the higher dosages caused fever, low blood pressure, hyperpnea, arrhythmia, and death from respiratory paralysis. The compound was among the most powerful of stimulants of cellular metabolism.

Tainter *et al.* (1935) confirmed the latter observations but found that the compound failed to stimulate metabolism in man and in rat. These workers found that 2-4-dinitro-6-cyclohexylphenol was 15 per cent less toxic to the pigeon than 2-4-dinitrophenol, and that a dosage of 20 milligrams per kilogram was fatal to dogs.

In connection with the use of 2-4-dinitro-6-cyclohexylphenol as an insecticide, Kagy (1936) has pointed out the probability that the compound is not very toxic to man and several other vertebrates on which it has been tested.

Because of the increasing importance of 2-4-dinitro-6-cyclohexylphenol as an insecticide and because of its relation to 2-4-dinitrophenol, Hrenoff & Leake (1939) studied the toxicity of the compound on three species of mammals. The following excerpt was taken from the summary of their work.

"The minimal lethal dose range of 2-4-dinitro-6-cyclohexylphenol on single subcutaneous administration in olive oil to mice and guinea pigs lies between 20 and 45 milligrams per kilogram; on oral administration, it extends from 50 to 125 milligrams per kilogram. As with nitrated phenols generally, the symptoms of toxicity are hyperthermia, hyperpnea, and convulsions. Repeated daily oral doses of 5 milligrams per kilogram had no effect in guinea pigs over a two-weeks observation period. One-half of 1 per cent of the chemical in the diet of rabbits caused a 12-per cent average weight loss in a similar time."

It is apparent from the mammalian toxicological work that 2-4-dinitro-6-cyclohexylphenol is toxic in only comparatively large dosages. The compound has not been demonstrated to be a stimulant of metabolism in man similar to 2-4-dinitrophenol. Many individuals, including the authors, have worked with the compound for long periods and under conditions of extensive exposure without apparent deleterious effects.

* Certain practical aspects of this subject are discussed by Boyce, A. M., D. T. Prendergast, J. F. Kagy and J. W. Hansen. Dinitro-o-cyclohexylphenol in the control of mites on citrus and Persian walnuts, published in this number.

SUMMARY.—Dinitro-o-cyclohexylphenol, a yellowish-white, crystalline and nearly odorless compound, has been used in insecticide investigations at the Citrus Experiment Station since 1935. Certain of its physical and chemical properties that may concern its use on citrus and certain other plants have been investigated.

A satisfactory colorimetric method of analysis has been developed. The solubility of the dinitro-o-cyclohexylphenol in various organic solvents, including petroleum spray oils, and in water has been determined. The solubility of the compound in water increases with a rise in pH.

The distribution of the compound between the oil and aqueous phases of spray emulsions has been investigated. In acidified emulsions (pH 3.5 to 5.0) over 90 per cent of the compound remains in the oil phase at equilibrium. In alkaline waters (pH 8.0 to 11.0) less than 5.0 per cent of the compound remains in the oil phase. The phase distribution of dinitro-o-cyclohexylphenol greatly affects the toxicity of emulsions containing this compound to the eggs of the citrus red mite, *Paratetranchyus citri* (McG.), and to the eggs of the plant bug, *Lygaeus kalmii* Stål.

Field investigations have shown that certain oil emulsions containing dinitro-o-cyclohexylphenol are effective in the control of the black scale, *Saissetia oleae* (Bern.), the citricola scale, *Coccus pseudomagnoliarum* (Kuw.), the citrus red mite, *Paratetranychus citri*, the citrus whitefly, *Dialeurodes citri* Ashm., the European elm scale, *Gossyparia spuria* (Mod.), the walnut scale, *Aspidiotus juglans-regiae* Comst., and the frosted scale, *Lecanium pruinosum* Coq.

An investigation concerned with the use on citrus of dinitro-o-cyclohexylphenol in certain water-insoluble organic solvents other than petroleum oil has shown that emulsions of these solutions are appreciably toxic to the black scale. Tree-tolerance experiments showed that there was a direct relation between the boiling point of the solvent and the degree of injury resulting from these spray mixtures on citrus.

The effectiveness of aqueous solutions of dinitro-o-cyclohexylphenol for the control of the black scale on citrus has been investigated during the last two years. In this connection the sodium and triethanolamine salts have offered promise. Physical properties and methods of preparation of these salts as related to field usage have been studied. Field results indicate that aqueous sprays containing 0.035 per cent dinitro-o-cyclohexylphenol in solution as the sodium or triethanolamine salt will afford satisfactory control of the black scale on citrus.

Colloidal dispersions of this compound prepared and used in several ways have afforded high mortalities of the black scale and of eggs of the citrus red mite.

A dust mixture which contains 1 per cent of this compound incorporated in either walnut-shell flour or redwood-bark flour has proved to be an effective acaracide for the control of the citrus red mite on citrus and the common red spider, *Tetranychus telarius* (L.), on Persian walnuts.

Experiments on the control of the orange tortrix, *Argyrotaenia citrana* (Fern.), the citrus thrips, *Scirtothrips citri* (Moult.), the greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), and red scale, *Aonidiella aurantii* (Mask.), have shown that the compound is toxic to these insects, but for various reasons its use is not likely to be practical under field conditions.

Considerable attention has been directed to the phytocidal action of this compound when applied to citrus and other plants under a wide range of meteorological conditions in various insecticidal combinations. Although dinitro-o-cyclohexylphenol may cause injury to citrus and other subtropical plants under certain conditions, the indications are that it can be used with comparative safety on these plants, especially in dust mixtures and possibly in aqueous dispersions.

The relation of dinitro-o-cyclohexylphenol to public health has been considered. Available evidence does not indicate the existence of a problem in this regard.

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LITERATURE CITED

Borden, A. D. 1934. The tank-mixture method for dormant oil spraying of deciduous fruit trees in California. Calif. Ag. Exp. Sta. Bul. 579: 1–20.

Boyce, A. M., and D. T. Prendergast. 1936. Dinitro-ortho-cyclohexylphenol offers promise in control of citrus red mite. JOUR. ECON. ENT. 29(1):218–9.

Dutton, W. D. 1936. Orchard trials of dinitro-o-cyclohexylphenol in petroleum oil for control of rosy apple aphis and San José scale. JOUR. ECON. ENT. 29(1):62–5.

Garman, Philip. 1938. Control of the rosy apple aphid in Connecticut apple orchards. Conn. Ag. Exp. Sta. Circ. 126: 1–16.

Hammer, O. H. 1938. The scurfy scale and its control. JOUR. ECON. ENT. 31(2):244–9.

Hansberry, T. R., and C. H. Richardson. 1936. Toxicity of certain stomach poisons to several common lepidopterous larvae. JOUR. ECON. ENT. 29(6):1160–6.

Hartzell, F. Z., and J. B. Moore. 1937. Control of oystershell scale on apple by means of tar oils, tar lubricating oils, and lubricating oils containing dinitro-o-cyclohexylphenol. JOUR. ECON. ENT. 30(4):651–5.

Hartzell, F. Z., J. B. Moore and D. E. Greenwood. 1938. Control of eye-spotted budmoth on apple by lubricating oil containing dinitro-o-cyclohexylphenol. JOUR. ECON. ENT. 31(2):249–53.

Heymans, C., and H. Casier. 1935. Recherches sur l'action de differents nitro derives sur le metabolisme et sur le temperature. Arch. Internatl. Pharmacodyn. 50: 20–63.

Hrenoff, A. K., and C. D. Leake. 1939. Toxicity studies on 2-4-dinitro-6-cyclohexylphenol, a new insecticide. Univ. Calif. Publ. Pharmacol. 1(12):151–60.

Kagy, J. F. 1936. Toxicity of some nitro-phenols as stomach poisons for several species of insects. JOUR. ECON. ENT. 29(2):397–405.

Kagy, J. F., and C. H. Richardson. 1936. Ovicidal and scalicidal properties of solutions of dinitro-o-cyclohexylphenol in petroleum oil. JOUR. ECON. ENT. 29(1):52–61.

Smith, R. H. 1932a. Experiments with toxic substances in highly refined spray oils. JOUR. ECON. ENT. 25: 988–90.

Smith, R. H. 1932b. The tank-mixture method for using oil spray. Calif. Ag. Exp. Sta. Bul. 527: 1–86.

Tainter, M. L., F. W. Bergstrom and W. C. Cutting. 1935. Metabolic activity of compounds related to dinitrophenol. Jour. Pharm. and Exp. Therap. 53(1):58–66.

Dinitro-O-Cyclohexylphenol in the Control of Mites on Citrus and Persian Walnuts*†

A. M. BOYCE, D. T. PRENDERGAST,‡ J. F. KAGY** and J. W. HANSEN,‡
University of California Citrus Experiment Station, Riverside

The problem of mites and their control on subtropical fruits has been of increasing importance in California for the past 10 years. Biological and toxicological studies which pertain to several of the most important species have been actively pursued at this institution for the past 5 years.

THE MITE PROBLEM ON CITRUS.—The citrus red mite, *Paratetranychus citri* (McG.), locally known as the citrus red spider, is one of the major pests of citrus in California, where the total acreage affected probably exceeds 125,000 acres. It is the most important of the several species of mites that attack citrus in this state. The six-spotted mite, *Tetranychus sexmaculatus* Riley, is of importance in limited areas only, and the common red spider, *Tetranychus telarius* (L.), has been observed in economic proportions on several occasions during the past 2 years in an individual grove of navel orange, grapefruit, lemon and citron. The citrus rust mite or silver mite, *Phyllocoptes oleivorus* Ashm., usually constitutes a problem in only one small area on lemons. The citrus bud mite, *Eriophyes sheldoni* Ewing, a recently described species and a relatively new pest of lemons, constitutes a problem in only one locality.

Petroleum oil is the principal material used for the control of the citrus red mite, the six-spotted mite and the citrus bud mite. The proprietary selenium preparation *Selocide* (Hoskins *et al.* 1938) is effective in the control of the first two species but it is not widely used at present. Lime sulfur, ammonium polysulfide and sulfur dust cannot generally be relied upon for control of the citrus red mite and, although these materials are effective in controlling the six-spotted mite, they are not widely used for this purpose since it is

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† Early publication of this paper has been secured by payments of the printing charge.

‡ Formerly assistant in research.

** Investigator for the Crop Protection Institute.

usually necessary to consider the control of both species with the same treatment. Preliminary studies indicate that lime sulfur and ammonium polysulfide are both fairly effective in reducing populations of the citrus bud mite although an entirely satisfactory control program for this species is yet to be developed. Sulfur dust is very effective in controlling the silver mite and constitutes the standard treatment where control measures are required in seasons when petroleum oil is not being used for the combined control of scale insects and mites. In view of the general importance of the citrus red mite in particular and the fact that it is inadvisable to use oil sprays under a wide variety of conditions, an urgent demand has been created for a material other than oil to cope with this problem.

THE MITE PROBLEM ON PERSIAN WALNUTS.—The common red spider, *Tetranychus telarius*, is an important pest of Persian walnuts in certain seasons in several areas of the state. The Pacific mite, *Tetranychus pacificus* McG., occurs apparently on walnuts in mixed populations with the common red spider in the San Joaquin Valley, although the extent of injury caused by this species has not been determined. The clover mite, *Bryobia praetiosa* Koch, is commonly present but can scarcely be considered even of minor importance. The citrus red mite, *Paratetranychus citri* is occasionally abundant in walnut orchards interplanted with citrus. However, economic injury from this species has not been observed to date on walnuts. The European red mite, *Paratetranychus pilosus* (C. & F.), was found on walnuts in 1936 by the senior author. This was evidently the first record of the species in southern California. The mite, *P. ilicis* McG., also occurs on walnuts. Neither *P. pilosus* nor *P. ilicis* has been considered of economic importance on walnuts. However, Smith's* observations during the 1938 season in several coastal localities indicated that both of these species were responsible for commercial injury on walnuts. The walnut blister mite, *Eriophyes tristriatus erineous* Nal., is very commonly present on walnuts, although it is not considered economically important.

Petroleum oil sprays have not proved satisfactory in control of the common red spider on walnuts. Under certain conditions sulfur dust affords satisfactory control; however, its use on walnuts is attended with considerable hazard of injury under high temperature conditions. The proprietary selenium preparation, *Selecide*, affords excellent control of this mite on walnuts; but owing to the relatively high cost of spraying mature walnut trees and because of the erratic development of mite infestation in an individual grove, growers are generally prone to delay treatment until serious injury has occurred. Therefore, an effective and relatively inexpensive method of controlling the common red spider on walnuts would be of considerable value to the industry.

ADVANTAGES OF A METHOD OF MITE CONTROL BY MATERIALS APPLIED AS DUST.—The principal advantages of employing a method of mite control in which the material may be applied as dust are rapid application and low application costs. The use of dust acaricides in the citrus and walnut areas is particularly desirable in regions of scant rainfall. On citrus, control measures for the citrus red mite are most commonly necessary during the dry season, and this is always the case in the control of the common red spider on walnuts. An especially advantageous feature of a material applied as a dust for mite control is that it should not be dependent upon a temperature relationship for effectiveness.

DINITRO-O-CYCLOHEXYLPHENOL IN RELATION TO THE CONTROL OF MITES ON CITRUS AND PERSIAN WALNUTS.—The relatively new compound, dinitro-o-cyclohexylphenol, has been included in the University of California's general insecticide studies since August, 1935. Applied as sprays and dusts, it exhibited interesting possibilities at the outset for use in the control of mites.

Kagy & Richardson (1936) reported that a possible synergistic action results from combinations of a dinitro-o-cyclohexylphenol and petroleum oil. Therefore, in the earlier work with this compound applied as a spray, it was dissolved in highly refined petroleum oil because control measures for mites on both citrus and walnuts are of necessity applied to trees in foliage. Owing to the occurrence of injury to foliage and fruits, it has not been possible to use an oil solution of the com-

* Smith, R. H., University of California at Los Angeles. Manuscripts in press.

pound at a dosage adequate to insure entirely satisfactory results. However, experiments with several of the salts of this compound dissolved in water are now yielding promising results, particularly on citrus.

The toxicity to the citrus red mite of dinitro-o-cyclohexylphenol used in dust mixtures was recognized early in these studies. Therefore, this phase of the work has received considerable attention. Over 50 different kinds of dust mixtures employing this compound as the toxicant have been prepared and tested for their effectiveness against mites and also for plant injury. At first, dust mixtures were prepared by atomizing an oil solution of the compound on to diatomaceous earth (Boyce & Prendergast 1936) in an attempt to utilize the possible synergism previously mentioned. Mixtures that contained 0.5 and 1.0 per cent of the toxicant were studied in relation to control of the citrus red mite and injury to citrus trees. The dusts afforded a high degree of mortality initially, but the length of time that the residues remained toxic to mites, although variable, was generally very short. Furthermore, injury to the tender new foliage usually occurred. Observations indicated that the presence of moisture on the foliage from dew or fog at the time of application of the dust mixture or shortly thereafter was related to this injury. Laboratory tests demonstrated that the diatomaceous earth is preferentially wetted by water over oil. Therefore, in the presence of water, the oil plus the nitro-phenol is displaced from the dust. This factor was found to be partially responsible for the injury obtained.

Numerous materials were tested in an effort to impart properties to the oil that would cause it to wet the earth in the presence of water. This was best accomplished through the use of aluminum dinaphthenate dissolved in the oil at a concentration of 6 per cent by weight. The degree of injury was reduced considerably as a result of this procedure. As the study progressed, the inclusion of oil in the dust mixture proved to be unnecessary and was discontinued. Tests with several concentrations of the compound in various types of mixtures utilizing diatomaceous earth, talc, hydrated lime and bentonite were then conducted. A concentration of 1 per cent by weight appeared to be the upper limit that could be used with respect to foliage tolerance; however, a slight amount of injury to new growth commonly occurred.

Although high mortalities were obtained initially with these dusts, the residual action in all instances was variable and of short duration. Examination of these dust mixtures indicated that salts of the nitro-phenol were formed in each instance. Subsequent tests showed that when dinitro-o-cyclohexylphenol is incorporated in dust mixtures in which certain grades of diatomaceous earth, talc, hydrated lime, bentonite and other alkaline materials are used as diluents, salts or phenates are rapidly formed. Salts also occurred in the earlier dust mixtures studied in which an oil solution of the toxicant was used to incorporate it with diatomaceous earth. The formation of salts is greatly accelerated by moisture. These phenates are water-soluble in varying degrees, and certain evidence indicates that they may have been responsible for injury to the tender new foliage. In addition, it is probable that these phenates are dissipated readily through the action of weathering factors, which would explain the rapid and variable loss of toxicity of the material to mites after application.

When it became evident that dinitro-o-cyclohexylphenol reacts with basic ions in certain diluents to form salts, a study of diluents was undertaken. Dinitro-o-cyclohexylphenol is a pseudo acid and forms brilliant orange-colored salts. Many of the common diluents give basic reactions; therefore, measurement of the pH of 1 to 4 slurries affords a criterion for comparing various diluents.

A search was made for dust diluents, the slurries of which would be acidic and therefore would not react with the phenol to form salts. Lignocellulosic substances contain varying quantities of natural organic acids, and the slurries of the ground materials give pH values less than 7, so that they function to some degree as acid buffers. Of the lignocellulosic dust materials that were readily available during early stages of the experimental work, walnut-shell flour and redwood-bark flour offered the most promise. Both of these products had potential possibilities because they could be obtained readily in large quantities from California indus-

tries and, furthermore, they appeared to possess more of the imperative physical and chemical qualifications.

Certain of the physical and chemical properties of walnut-shell flour and redwood-bark flour compared with talc and diatomaceous earth are given in table 1.

Table 1 shows that walnut-shell flour and redwood-bark flour are slightly dissimilar in their properties. Screen analyses by the wet-sieving method* show that the sample of walnut-shell flour possesses a higher percentage of relatively coarse particles than does redwood-bark flour. In the case of walnut-shell flour, 76.1 per cent passed through a 325-mesh screen, whereas with redwood-bark flour 92.8 per cent passed through. This difference is not surprising in view of the fact that walnut shells are very hard and therefore difficult to grind.

Table 1.—Certain physical and chemical properties of several types of diluents used with dinitro-o-cyclohexylphenol in dust mixtures.

Physical and Chemical Properties	Talc	Diatomaceous Earth			Walnut-Shell Flour	Redwood-Bark Flour
		No. 1	No. 2	No. 3		
pH of 1–4 slurry	9.80	8.30	7.20	5.51	5.40	2.44
Density-grams/cu. cm.	0.629			0.228	0.616	0.419
Screen tests						
Per cent on 200 mesh	0.1			0.80	6.60	1.40
Per cent through 200 mesh	99.90			99.20	93.40	98.60
Per cent on 325 mesh	0.00			0.20	17.30	5.80
Per cent through 325 mesh	99.90			99.00	76.10	92.80

Walnut-shell flour is less bulky than redwood-bark flour, which is a distinct advantage. The redwood-bark flour is much more acidic. This latter fact would give the redwood-bark flour an advantage from the standpoint of buffering activity, although that possessed by walnut-shell flour appears sufficient to prevent formation of salts of dinitro-o-cyclohexylphenol. In view of the high pH of a talc slurry, salts of the nitro-phenol are readily formed. The pH values given for diatomaceous earth slurries show considerable variation among materials from different sources. The diatomaceous earth used as a diluent in most of the studies was material no. 1 or no. 2 in table 1. Only recently has it been possible to obtain standardized grades of diatomaceous earth, such as material no. 3 in table 1, that are acidic and that are practical to use as diluents from the viewpoint of cost. However, diatomaceous earth is in general too bulky for practical field usage in this particular problem and, furthermore, its general properties are such that it is difficult to obtain satisfactory deposits on citrus trees.

Most of the laboratory and field experimentation has been conducted with walnut-shell flour and redwood-bark flour. Other lignocellulosic diluents with which limited laboratory and field work has been conducted include the following: redwood flour, pecan-shell flour, almond-shell flour, peach-pit flour, olive-pit flour, apricot-pit flour and three different hardwood flours. Many of these offer promise for use with dinitro-o-cyclohexylphenol.

Preparation of Dust Mixtures.—Two methods were employed in the preparation of dusts which contain dinitro-o-cyclohexylphenol: the mechanical, or ball-mill method, and the solvent-mix method. The mechanical method offered considerable difficulties. The nitro-phenol does not lend itself well to this type of mixing because certain of its physical properties tend to cause the crystalline particles to collect in aggregates. Fairly uniform dusts were prepared by mixing equal parts of diluent and nitro-phenol in a ball mill for periods ranging from 12 to 24 hours and then diluting this mix to the desired strength of nitro-phenol by an additional 4 hours of mixing.

The solvent-mix method consists in atomizing slowly a solution of the nitro-phenol in a suitable solvent (toluene 70 per cent plus carbon tetrachloride 30 per

* U. S. Treasury Dept. Proc. Div. Federal specifications for cement (methods for sampling, inspection and testing). 35 pp. Sept. 30, 1936 (published 1937). (Federal Standard Stock Catalog, SS-C-158.)

cent) into a special mixing apparatus that contains the diluent. The mixing machinery is in continuous operation during the process of atomization. After all the solution has been atomized and thoroughly mixed in the diluent, the dust is "fluffed" and is ready for use. This process does not usually exceed a period of 30 minutes.

The physical difference between the mechanically mixed dusts and the solvent-mixed dusts is best demonstrated by holding white paper saturated with sodium hydroxide solution (15 per cent) in the paths of blown dust of each type of mix. With the best mechanical mixture there are apparently large numbers of microscopic aggregates of the crystalline nitro-phenol that are changed to the orange-colored sodium salt on striking the wet alkaline paper. With the solvent type of mix the nitro-phenol is much more uniformly dispersed in the diluent.

The solvent-mix dusts have a decided advantage from the standpoint of the dispersion of the nitro-phenol and the economies involved in preparation. From a biological point of view, a significant difference has never been demonstrated in the degree of relative effectiveness obtained with dusts prepared by the two methods either in the laboratory or in the field.

A Study of Diluents as Related to Weathering and Mite Control.—Since preliminary work relating to different diluents had shown the superiority of walnut-shell flour and redwood-bark flour, it appeared desirable to study more completely the weathering of the nitro-phenol with these two diluents first, so as to be more readily able to judge the merits of new dust diluents. It was found that the reddish color of redwood-bark flour interfered materially with the analysis of the nitro-phenol; consequently, in the study of diluents as related to weathering and mite control, walnut-shell flour was employed as a standard for comparison.

Experiments were conducted to determine the periods of effectiveness of a dust mixture consisting of 1.0 per cent dinitro-o-cyclohexylphenol incorporated with walnut-shell flour. This preparation will hereafter be referred to as the standard dust mixture. The tests were designed so that at definite intervals after application both the deposit of the nitro-phenol and the effectiveness in producing mortality of the citrus red mite could be ascertained. The following experimental design was employed: A sufficient number of grapefruit for the experiment were washed and dried. Fruits to be used as checks were dusted uniformly with walnut-shell flour by means of a precision laboratory duster. The remaining fruits were precisely dusted with the standard dust mixture. The deposit on the surface of the fruit was regulated to be as near as possible to the deposit obtained in the field. All fruits were placed outside under conditions that were decided to be representative of field conditions. Initially, 20 fruits dusted with the standard dust mixture were washed with acetone and the washings were analyzed for the nitro-phenol by means of a colorimetric analysis.* The washed fruits were measured with a vernier caliper and the amount of the compound in micrograms (μg) per square centimeter of surface was computed. Ten fruits dusted with walnut-shell flour (checks) and 10 fruits dusted with the standard dust mixture were removed to the insectary. In accordance with the following systems, these dusted fruits were infested with about 25 adult female mites each: One fruit from the check and one from the treatment were infested with mites simultaneously, so as to insure the transference of mites from the same population to each check and treated fruit. This technique tends to compensate for heterogeneity due to population differences.

At different intervals up to one week, the deposit of dinitro-o-cyclohexylphenol on the surface of the fruit was ascertained, and the toxicity to the citrus red mite of these deposits of the nitro-phenol was determined. The results of the toxicity portion of the experiment will be taken up under the subject of the relation of deposit to toxicity (see the section, "Relation of Deposits to the Toxicity of a 1 Per Cent Dinitro-O-Cyclohexylphenol–Walnut-Shell Flour Dust Mixture.")

The results of four weathering experiments are summarized in table 2, and the data are plotted in fig. 1. The weather conditions for the experiments were different, and the results as evidenced by the

* Boyce, A. M., J. F. Kagy, C. O. Persing and J. W. Hansen. Studies with dinitro-o-cyclohexylphenol, published in this number.

Table 2.—Rate of weathering of dinitro-o-cyclohexylphenol from the standard dust mixture.

EXPERIMENT NO.	EXPOSURE TIME (DAYS)	MICROGRAMS OF DN* PER SQ. CM. OF FRUIT SURFACE
A	0	0.981
	3	1.000
	4	0.363
	5	0.221
B	0	0.72
	3	0.28
	4	0.21
	5	0.16
C	0	0.62
	1	0.29
	3	0.15
D	0	0.356
	1	0.220
	3	0.088
	6	0.039

* DN = Dinitro-o-cyclohexylphenol.

curves are likewise different. The initial deposits were different, and the rate of decrease of the nitro-phenol from the surface of the fruit varied considerably. The amount of dinitro-o-cyclohexylphenol lost from the fruit surfaces is inversely related to the exposure time. The curves are of the same general character, with the exception of curve *A*. For the first 3 days of this experiment the temperature did not exceed 60 degrees F.; and because of intermittent rains it was necessary to keep the fruit covered with a canvas tent. During this period there was no measurable loss of the nitro-phenol from the fruit surfaces. After the third day the weather cleared and the maximum temperature increased to about 85 degrees F. for the remainder of the experiment. Fair weather prevailed for experiments *B*, *C* and *D*, with maximum temperatures ranging between 70 degrees and 85 degrees F., and minimum temperatures ranging between 30 degrees and 40 degrees F.

This apparent effect of temperature on weathering of dinitro-o-cyclohexylphenol dust residues was observed in field work with dust mixtures composed of 1 per cent of the nitro-phenol with either walnut-shell or redwood-bark flour as the diluent. Certain of these tests indicated that the length of time after application during which residues remained toxic to newly hatched mites was related to existing temperature conditions. The period of residual toxic action was shorter under high temperature conditions than under cool conditions. It was also observed that the incidence of plant injury was related to high temperature. The relative humidity is usually very low, *i.e.*, about 10 to 20 per cent, and the sunlight intense when high temperatures exist; on the other hand, during cool weather, the relative humidity usually varies from 50 to 80 per cent, often with overcast skies. Hence, it was necessary to consider the role of temperature, relative humidity, and light intensity in a study of the factors that relate to weathering of the compound. It was also apparent that if accurate comparisons of dust diluents as related to effectiveness of dinitro-o-cyclohexylphenol dust mixtures were to be made, a standardized or artificial weathering technique for the dusts must be adopted.

Effect of Temperature.—The following procedure was employed in studies of the effect of temperature upon weathering of dinitro-o-cyclohexylphenol. Approximately 200 grapefruit of about the same size and free from blemishes were uniformly dusted with the standard dust mixture by means of a laboratory precision duster. The dusted fruits were divided into nine samples of 20 fruits each, because it had been shown by experiment that this number of fruits was more than adequate for the determination of the deposit of the nitro-phenol per unit area. The dusted fruits were also divided into groups at random so as to reduce to the minimum experimental error, caused

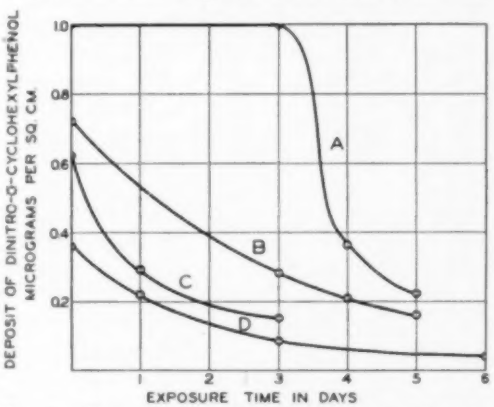

FIG. 1.—Rate of weathering of dinitro-o-cyclohexylphenol from the standard dust mixture.

by inherent variations in deposits. One sample of 20 fruits was employed for the determination of initial deposit and two samples each of the remaining eight were placed at temperatures of 80, 85, 100 and 112 degrees F., respectively. After intervals of 24 and 48 hours, a sample from each temperature was removed and the deposit of the nitro-phenol in micrograms per square centimeter was determined.

The results for two of these temperature experiments with initial deposits of 2.11 and 0.804 micrograms per square centimeter, respectively, are summarized in table 3. In fig. 2, the residues of the nitro-phenol remaining after 24 and 48 hours have been plotted against temperatures. The curves illustrate that temperature has a significant role in the weathering of the nitro-phenol. There is a very rapid loss of the compound between 80 and 90 degrees F.

At temperatures above 90 degrees F., the rate of weathering due to temperature is not so rapid. The percentage decrease of the nitro-phenol is greater from 80 to 90 degrees F. than from 90 to 112 degrees F. Experiments relative to the effect of temperatures below 80 degrees F. have shown that the percentage decrease of dinitro-o-cyclohexylphenol is considerably less, and at temperatures of about 60 degrees F. and lower the effect of temperature is nil. In fig. 1, curve *A* illustrates that over a period of 3 days, when the maximum temperature did not exceed about 60 degrees F., there was no measurable loss of dinitro-o-cyclohexylphenol from fruit surfaces.

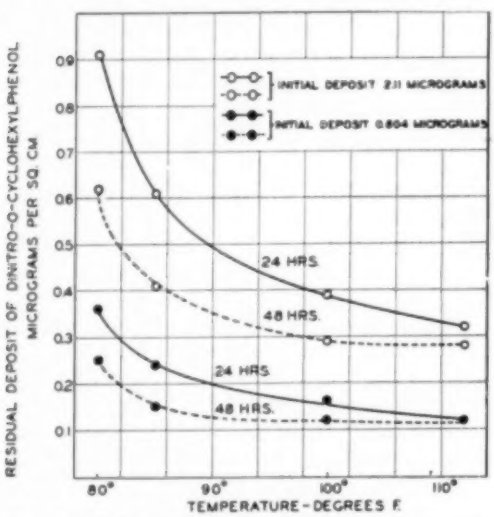

FIG. 2.—Effect of temperature on weathering of dinitro-o-cyclohexylphenol from the standard dust mixture.

Table 3.—Effect of temperature on the weathering of dinitro-o-cyclohexylphenol from the standard dust mixture.

INITIAL DEPOSIT of DN* (μG./SQ. CM.)†	TEMPERATURE IN DEGREES F.	RESIDUAL DEPOSIT 24 HOURS† (μG./SQ. CM.)	RESIDUAL DEPOSIT 48 HOURS† (μG./SQ. CM.)
2.11	80	0.91	0.62
	85	0.61	0.41
	100	0.39	0.29
	112	0.32	0.28
0.804	80	0.36	0.25
	85	0.24	0.15
	100	0.16	0.12
	112	0.12	0.12

* DN = Dinitro-o-cyclohexylphenol.
† Deposit data in micrograms of DN per square centimeter.

Effect of Sunlight.—A sufficient number of grapefruit were dusted with the standard dust mixture. Half the dusted fruits were placed under a mercury vapor sunlamp (General Electric) about 70 degrees F., and the remainder were placed at about 70 degrees F. in darkness. Initially and at intervals of 24 and 48 hours samples of fruit were taken and the deposit in micrograms of dinitro-o-cyclohexylphenol per square centimeter of surface was determined. In the room where fruits were exposed to light, the illumination was continuous for 8 hours during each 24-hour period. The data obtained are given in table 4.

The difference between the deposits determined on the fruits exposed to the light versus those in darkness are of a magnitude that could be ascribable to small fluctuations of temperature and ex-

Table 4.—Effect of light on the weathering of dinitro-o-cyclohexylphenol from the standard dust mixture. Temperature about 70 degrees F. Relative humidity about 35 per cent.

EXPOSURE TIME	DEPOSIT OF DN* IN MICROGRAMS PER SQUARE CENTIMETER OF FRUIT SURFACE	
	Experiment A	Experiment B
None	0.179	0.948
8 hours light+16 hours dark	.154	.552
24 hours dark	.163	.682
16 hours light+32 hours dark	.154	.451
48 hours dark	0.165	0.648

* DN = Dinitro-o-cyclohexylphenol.

perimental error. It is not assumed that the light has no effect on the nitro-phenol, since organic compounds usually undergo varying degrees of decomposition when exposed to sunlight. However, under the conditions of this experiment, the decomposition taking place could not be determined, and it may be concluded that the effect of light as compared with that of temperature is of negligible importance.

Effect of Humidity.—One hundred grapefruit were precisely dusted with the standard dust mixture; 20 fruits were used to analyze for initial deposit; 20 fruits were placed in a cabinet that ranged from 0 to 10 per cent relative humidity; 20 fruits at 37 per cent relative humidity; 20 fruits at 70 per cent relative humidity; and 20 fruits were placed at saturated humidity. The temperatures of the cabinets were maintained at approximately 85 degrees F. After 24 hours the fruits were removed from the cabinets, washed with acetone and the amounts of dinitro-o-cyclohexylphenol in micrograms per square centimeter were determined. The data obtained are summarized in table 5.

Table 5.—Effect of humidity on the weathering of dinitro-o-cyclohexylphenol from the standard dust mixture. Temperature about 85 degrees F.

Initial Deposit of DN* in Micrograms Per Square Centimeter	Relative Humidity, Per Cent	Residual Deposit After 24 Hours (μg./sq. cm.)
0.234	0–10	0.076
	37	0.088
	70	0.078
	95–100	0.071

* DN = Dinitro-o-cyclohexylphenol.

The only discrepancy among the data in table 5 is the value obtained at 37 per cent relative humidity. During the 24-hour period the temperature was known to have dropped several degrees. In view of the uniformity of the residual deposits over the range of relative humidities and under prevailing conditions it can be safely concluded that humidity has little or no relation to the dissipation of the nitro-phenol.

Upon conclusion of the experiments on the factors that relate to weathering of a 1 per cent dinitro-o-cyclohexylphenol–walnut-shell flour dust mixture, it was decided to neglect humidity and light and to weather artificially the dusted fruits at a temperature of 85 degrees F.

Relation of Deposits to the Toxicity of a 1 Per Cent Dinitro-O-Cyclohexylphenol–Walnut-Shell Flour Dust Mixture.—In connection with the weathering experiments and the relative effectiveness of different dust diluents for use with dinitro-o-cyclohexylphenol, numerous toxicity data have been obtained. As a foundation for further toxicological work the standard dust mixture, *i.e.*, 1 per cent dinitro-o-cyclohexylphenol incorporated with walnut-shell flour, was given more extensive consideration. Over a period of several months, mortality data were obtained with various deposits of the nitrophenol applied with walnut-shell flour and evaluated as micrograms of the compound per square centimeter of fruit surface.

The laboratory technique employed has been previously described in connection with the weathering experiments (see the section, "A Study of Diluents as Related to Weathering and Mite Control"). Vigorous adult female citrus red mites were transferred simultaneously with the aid of a needle to fruits: (1) treated with the standard dust mixture, and (2) treated with walnut-shell flour alone. Each infested fruit was placed on an individual sheet of paper and the numbers of dead and live mites were recorded for a period of 3 days at intervals of approximately 24 hours. The mites employed in the tests were considered to be representative of those found under field conditions. The technique of transferring mites to the surface of dusted fruits rather than dusting mites directly was considered to be a critical test of the materials.

In table 6, the toxicity data have been arrayed according to deposits of the nitro-phenol in micrograms per square centimeter of fruit surface. The mortalities obtained at the various deposits have been plotted in fig. 3. The sigmoid type of curve shows that the lethal deposit of dinitro-o-cyclohexylphenol applied in a 1 per cent dust mixture with walnut-shell flour is about 0.4 microgram per square centimeter.

This minute lethal deposit is illustrative of the high toxicity of the compound to the citrus red mite. The speed of toxic

action is rather interesting. With lethal dosages of the dust the mortality is complete within 24 hours, with an appreciable mortality after a few hours. The fact that a relatively small percentage of the surface of the mite's body is in contact with the dust is further evidence of its high toxicity.

The deposit of dinitro-o-cyclohexylphenol lethal to immature forms would probably be considerably less than 0.4 microgram per square centimeter. Also the lethal deposit required for the adult mites when applied directly to the body as is the case in the field would probably be considerably less than 0.4 microgram per square centimeter. When fruits heavily infested with mites in all stages of development, including eggs, are dusted with lethal deposits of the dust under laboratory conditions, the population is annihilated.

It was of interest to obtain in the field some deposit and weathering data for the standard dust mixture and to ascertain whether the deposits of the nitro-phenol obtained were comparable to the lethal deposits determined under laboratory conditions. An experiment was designed whereby three groups of 10 trees each were dusted with field equipment under the following conditions: two groups were treated with dosages of 1 pound and 2 pounds per tree, respectively, under conditions of low relative humidity, *i.e.*, approximately 20 per cent; whereas, the third group was treated with a dosage of 2 pounds per tree when the relative humidity was high, *i.e.*, approximately 80 per cent. The dew point had not been reached in any instance when the dust was applied. As an initial sample, 25 leaves were picked from each of ten trees immediately after dusting. Thereafter leaf samples were taken at 48-hour intervals. The leaves were washed with acetone* and the deposit of the nitro-phenol was determined in micrograms per square centimeter, by the method of colorimetric analysis.†

Table 6.—Toxicity of a 1 per cent dinitro-o-cyclohexylphenol–walnut-shell flour dust mixture to adult female citrus red mites.

Dosage of DN* in Micrograms Per Square Centimeter	Total Number Adult Mites	Per-centage Mortality	Net Per-centage† Mortality
1.000	505	100.0	100.0
0.981	493	100.0	100.0
0.702	388	100.0	100.0
0.450	239	100.0	100.0
0.363	476	96.3	96.2
0.362	283	100.0	100.0
0.356	289	100.0	100.0
0.277	380	95.9	95.5
0.260	396	91.2	90.6
0.220	459	92.8	92.2
0.220	455	47.7	44.1
0.180	341	79.8	76.5
0.162	308	69.2	65.5
0.115	353	90.5	90.2
0.088	474	45.2	38.0
0.062	374	13.3	8.3
0.060	373	7.6	1.9
0.039	379	20.8	7.4

* DN = Dinitro-o-cyclohexylphenol.
† Net mortality computed by Abbott (1925) formula.

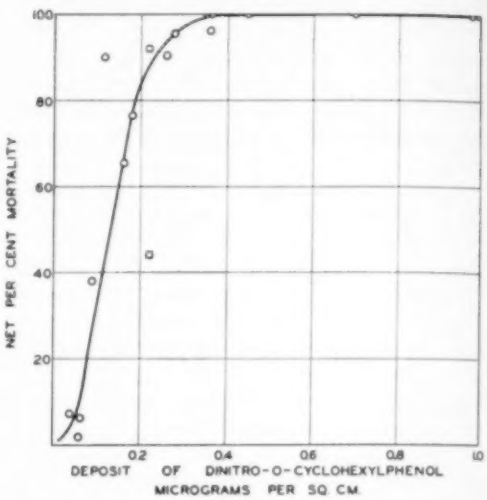

FIG. 3.—Toxicity of a 1 per cent dinitro-o-cyclohexylphenol–walnut-shell flour dust mixture to adult female citrus red mites.

The data procured are summarized in table 7. Weathering curves obtained by plotting deposits against time in days are illustrated in fig. 4. These curves of the same general form as shown in fig. 1 are discussed under a study of diluents as related to weathering.

The data and curves show that under conditions of low relative humidity the deposit is much less than under more humid conditions. The deposits obtained under conditions of high relative humidity, curve *A*, fig. 4, resulted in a deposit

* It has been subsequently found that carbon tetrachloride is superior to acetone for this purpose.
† Boyce, A. M., J. F. Kagy, C. O. Persing and J. W. Hansen. Studies with dinitro-o-cyclohexylphenol, published in this number.

Table 7.—Weathering of dinitro-o-cyclohexylphenol from the standard dust mixture under field conditions.

Time in Days	Maximum Temperature, Degrees F.	Dosage 2 Pounds of Dust Per Tree (High Humidity)			Dosage 2 Pounds Dust Per Tree (Low Humidity)			Dosage 1 Pound Dust Per Tree (Low Humidity)		
		Total, DN* in Milligrams	Leaf Area in Square Centimeters	Micrograms Per Square Centimeter	Total DN* in Milligrams	Leaf Area in Square Centimeters	Micrograms Per Square Centimeter	Total DN* in Milligrams	Leaf Area in Square Centimeters	Micrograms Per Square Centimeter
Initial	67	—	—	—	2.78	4360	0.637	1.065	4134	0.256
2	82	5.14	4366	1.17	1.89	4844	0.390	0.857	4278	0.200
4	87	4.32	3842	1.12	1.73	4270	0.400	0.627	3386	0.185
6	87	—	—	—	0.965	3560	0.271	0.575	3444	0.166
7	84	3.25	4296	0.756	—	—	—	—	—	—

* DN = Dinitro-o-cyclohexylphenol.

nearly twice as great as that obtained when the same amount, 2 pounds, was applied at low relative humidity, curve *B*, fig. 4.

Under laboratory conditions it was determined that the lethal deposit of the nitro-phenol was 0.4 microgram per square centimeter. The weathering data show that with an application of two pounds of dust per tree, applied under conditions of low relative humidity, the ethal deposit of 0.4 microgram per square centimeter was maintained for a period of approximately 4 days under moderate temperature conditions. However, under the same conditions of low relative humidity the application of 1 pound of dust per tree did not deposit an amount equivalent to the lethal deposit determined in the laboratory.‡

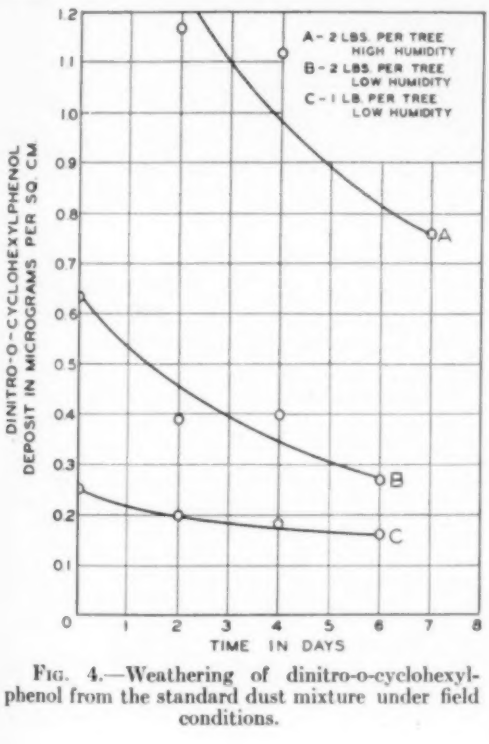

FIG. 4.—Weathering of dinitro-o-cyclohexylphenol from the standard dust mixture under field conditions.

It is hoped to obtain more detailed field data in the near future concerning deposits of the standard dust mixture under varying meteorological conditions. It is also hoped to complete more detailed laboratory experiments relative to the toxicity of the standard dust mixture to eggs, newly hatched mites and molting forms. As a result of such studies more complete information concerning the relation of deposit to the effectiveness of the compound for the citrus red mite will be possible.

USE OF DINITRO-O-CYCLOHEXYLPHENOL DUST ON CITRUS.—After various laboratory and field studies on the citrus red mite it became evident that a properly prepared solvent-mix dust, consisting of 1 per cent dinitro-o-cyclohexylphenol with walnut-shell flour or redwood-bark flour as the diluent, produced high mortalities of mites. It was also apparent that such a dust was reasonably safe for use in the field on a fairly large scale. As a result, an extensive field program was

‡ It has been observed on many occasions in connection with both experimental and practical dust application of several different insecticides and diluents that generally low deposits of the material are obtained under conditions of low relative humidity. This phenomenon appears to be related to so-called electrical conditions of the air. Under such conditions static electricity commonly "builds up" on the rubber-tired dusting equipment to such an extent (even though a drag chain contacts the earth) that a small arc resulting in a mild "shock" to the operator often occurs when a twig on a tree touches him.

undertaken in 1937, and during that season approximately 60,000 pounds of the dust mixture were prepared and applied. Several hundred acres including oranges, lemons and grapefruit were treated, the plots covering a wide range of conditions in various localities. After this work there developed a demand on the part of growers for the dust mixture. A proprietary product registered in the state of California as *DN Dust** was made dust with this material as diluent having been applied. Present indications are that it may be satisfactorily used as the diluent in dinitro-o-cyclohexylphenol dust mixtures on citrus and walnuts.

The density of the foliage and fruits on citrus trees renders it very difficult to deposit uniformly satisfactory quantities of a material applied as dust on all portions of the tree. Preliminary studies showed that a more thorough application

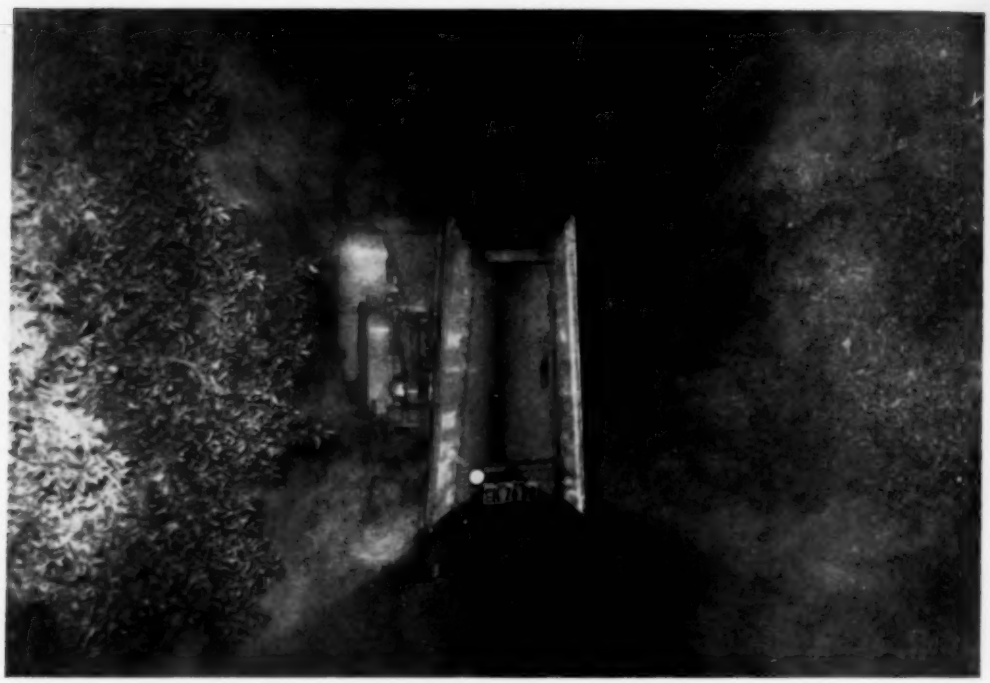

FIG. 5.—Rear view of a field duster in operation in a citrus grove.

available for limited commercial usage in April, 1938. It is prepared in accordance with the specifications developed in the experimental work and contains approximately 1 per cent dinitro-o-cyclohexylphenol with walnut-shell flour as the diluent. Approximately 1 million pounds of this dust mixture were applied commercially by the manufacturer during the 1938 season under a wide variety of conditions and under close supervision and control.

The field tests in which redwood-bark flour was employed as the diluent for dinitro-o-cyclohexylphenol have been extensive, approximately 16,000 pounds of

* Manufactured by The Dow Chemical Co., Long Beach, Calif.

was essential for best results in control of the citrus red mite than could be accomplished with available dusting equipment. This is because the mites and their eggs occur on both surfaces of the leaves and on all portions of the twigs, branches and fruits. Hence, a study of dusting equipment was undertaken in cooperation with O. C. French (1938), Division of Agricultural Engineering, University of California at Davis. This study has resulted in the development of improved equipment (figs. 5 and 6), many units of which have been recently constructed.

The general principles employed in this type of equipment are: (1) The use of a relatively large volume of air moving at a relatively low velocity (approximately

FIG. 6.—Field duster in operation in a citrus grove.

9,000 to 10,000 cubic feet per minute per discharge at approximately 65 miles per hour); (2) discharge of the air through two stationary "fan-shaped" or so-called "fish tail" vertical orifices, each of which is equipped with a simple, mechanically or manually operated movable deflecting device at the distal end. By slowly deflecting the air stream at the point of discharge, directing it forward and backward, the operator is able to agitate or move the foliage and fruit sufficiently to direct a blast of the air in such a way that the dust is carried to all surfaces.

The truck conveying the dusting equipment travels midway between two rows of trees at a speed of approximately 2½ miles per hour. The dust is discharged from two outlets, each of which is directed at the trees in the row adjacent. Thus, only one passage of the equipment in the center between two rows is necessary. Application of the dust is made from two sides of the trees in a given row and from many angles on an individual tree through the use of the deflecting device on the discharge. Citrus dusting is usually done at night in order to have the advantage of quiet air conditions.

The dosage of *DN Dust* required per mature tree varies in accordance with (1) the presence of fruit that is approximately one-half of full size to full size, (2) the presence or absence of moisture on the trees at the time of application and (3) in the case of oranges and grapefruit, the density of foliage on the tree. If there is no mature fruit on the tree or if the new crop has not attained half size, a dosage of 1 pound per tree per application appears to be adequate under most conditions. It is necessary to increase the dosage per tree as the fruit becomes larger, reaching the maximum of 2 pounds per tree under the most extreme conditions.

It is more difficult to obtain a satisfactory amount of material deposited on large citrus fruits than on the younger fruits and on the leaves. This appears to be related to (1) inherent differences in the surfaces concerned which affect the depositing properties of the dust mixture and (2) the presence of fruit in contact with other fruit in clusters, which does not permit of an adequate amount of uniformly deposited dust on the protected surfaces when low dosages are applied. On lemon trees where mature or nearly mature fruits may occur at all times of

the year, and where the foliage is characteristically less dense than on oranges and grapefruit, correspondingly larger dosages of dust per tree are required as compared with orange and grapefruit trees.

As has just been indicated, the amount of foliage has a bearing on the dosage requirements per tree and also on the mechanics of application. Sparsely foliated trees require higher dosages and the velocity of the air conveying the dust must be reduced considerably over the requirements for more densely foliated trees. The presence of an optimum amount of moisture on the trees from dew or fog enables a reduction of approximately 25 per cent of the normal dosage. Available field evidence indicates that the minimum normal dosage for trees that are approximately 6 feet or more in height is 1 pound per tree. On trees that are less than 6 feet in height, the dosage per tree is varied according to the size of the tree and the type of equipment used in applying the dust.

The number of applications required for satisfactory control depends upon several factors such as (1) variety of citrus, (2) season of year, (3) locality and (4) synchronization with control measures for other pests. In general, a program consisting of two properly timed applications is most dependable and appears to be most desirable, especially in those localities where mite population densities are usually high throughout the year or where in the early spring and fall high populations may be expected to persist for periods of 4 months or longer. However, additional information concerning this and other points relating to the use of *DN Dust* is needed and will be forthcoming with more extensive use of the material. During the spring and early summer of 1938, on large acreages of navel oranges in several localities, one application afforded control generally for a period of from 3 to 6 months, which condition was largely accounted for by the fact that in most instances a very high percentage of the eggs failed to hatch after the treatment. Also, climatic conditions existing for several months after treatment were not favorable for rapid increase in population densities. When climatic and other factors are favorable to the development of high populations, one treatment may generally be expected to afford control for a period of from 6 to 10 weeks.

When a program of two applications is adopted, the proper timing of the second treatment is essential for maximum efficiency in results. The timing of the second treatment depends upon the length of the period required for the hatching of all eggs present at the time of the first treatment. Generally all of the mites except the molting forms and a variable percentage of the eggs are killed by the first treatment. The residue is toxic to those mites emerging from the molt and also usually to those that are hatched within a period of 4 or 5 days after treatment. Since the eggs usually hatch within 10 days from deposition during the seasons of higher temperatures and within 14 days during seasons of lower temperatures, these periods in general represent the interval between the first and second applications. Eggs deposited prior to the first treatment that have not hatched at the time of the second treatment will hatch within several days thereafter, the young mites being killed by the residue.

Although the foregoing discussion applies particularly to control of the citrus red mite, the same general facts appear to apply to the control of the six-spotted mite and to the common red spider. However, since the latter species is not common on citrus, only a few infestations have been treated and in each instance one treatment afforded excellent results in control. In the studies with *DN Dust* on the combined control of the citrus red mite and the citrus rust mite or silver mite on lemons, the results on the silver mite have not been satisfactory, although when regular dusting sulfur was included in the mixture a very high degree of control was obtained. The *DN Dust* afforded a high degree of kill of the silver mite initially, but populations built up rapidly several weeks after treatment. This dust has no material value in the control of the citrus bud mite, which exists mostly inside the leaf and fruit buds and under the "buttons" of the fruits.

Throughout this study particular attention has been given to the matter of injury to citrus by dust mixtures containing dinitro-o-cyclohexylphenol. The most important factor relating to injury appears

to be the incidence of high temperature occurring within a period of 2 days after application. Present indications are that in general the critical temperature is above 95 degrees F. for all species and varieties of citrus investigated. The fruit and foliage on the southwest portion of the tree that is exposed to direct sunlight during the daily peak of the critical temperature may be burned. The injury most commonly occurs in the "benches" or "pockets" naturally formed by the configuration of the tree and is accentuated when there is little or no air movement in the grove during the period of critical temperature. However, when the official local weather forecasts have been carefully followed and the material was not applied when temperatures above 95 degrees F. were forecast, this injury has been of negligible economic importance. Another type of injury caused by this material is the light-colored "mottled" areas that develop in new leaves at a particular stage of development. Unless the degree of mottling is very severe, this is usually only a temporary effect since the leaf soon regains its normal color.

DN Dust is compatible with dusting sulfur and may be incorporated in the same mixture. Moreover, HCN fumigation may be carried on over fresh deposits of *DN Dust*, so that the use of this material has not adversely affected fumigation practice. Oil sprays may be applied with safety within 1 week after application of *DN Dust*, and *vice versa*. Studies are in progress regarding the compatibility of *DN Dust* with cryolite, nicotine, zinc oxide and certain other zinc compounds for possible use in combined treatments for citrus red mite, orange tortrix, citrus aphids and the correction of the mottle-leaf malady of citrus.

In summarizing the work with dinitro-o-cyclohexylphenol in dust mixtures used on citrus, it may be said that the material offers considerable promise for extensive usage in the control of the citrus red mite. Much more information is needed regarding various phases of the use of this material. This information can be obtained only by observation over an extended period of time and over a wider range of seasonal conditions than can be encountered within 2 years.

THE USE OF DINITRO-O-CYCLOHEXYLPHENOL DUST ON PERSIAN WALNUTS.—Studies with dust mixtures containing dinitro-o-cyclohexylphenol used on walnuts in the control of the common red spider have been in progress during the past three seasons. The work in 1938 was the most extensive, involving about 300 acres of walnuts, and was designed to study dosage requirements per tree and the timing of applications. The proprietary product was not available for commercial usage on walnuts in 1938, although it was used in most of the tests. Direct comparisons were generally made between *DN Dust* and a dust mixture utilizing the same toxicant and in which redwood-bark flour constituted the diluent. In certain instances dusting sulfur was included in the regular *DN Dust* mixture. Infestations of the common red spider did not develop into economic proportions until August, which is relatively late in the season. Under the existing conditions one treatment with a dosage of 3 pounds of the dust mixture per mature walnut tree afforded satisfactory control throughout the remainder of the season, approximately 6 weeks. There was no measurable difference in the performance between the mixture with walnut-shell flour and that with redwood-bark flour.

The observations indicate that the common red spider is more susceptible to dinitro-o-cyclohexylphenol than is the citrus red mite. The active mites and a variable percentage of the eggs are killed by the dust, even where extensive webbing exists. The mites that are molting at the time of treatment and those that are subsequently hatched from eggs present at the time of treatment are generally killed by the residues when they emerge. It appears that the incubation period of the eggs of this mite is generally less than 5 days under summer conditions when treatment is required. Since the residue of *DN Dust* is usually effective for 4 or 5 days after application, this apparently explains the excellent results in control obtained from one treatment. Because of this, data relating to the timing of treatments are not available; in fact, at the present time it appears that it may be more desirable to apply a single treatment with plans to apply another later if the mite population builds up rather than to attempt to follow a program of timed treatments.

In those instances where dusting sulfur was incorporated in the *DN Dust* mixture, there was no measurable degree of improvement in the control obtained. Furthermore in most cases injury to the foliage and green husks of the nuts occurred, which was evidently due to the sulfur in the mixture.

Although the foregoing discussion applies specifically to the common red spider, good mortalities have been obtained with *DN Dust* on the clover mite and on the citrus red mite on walnuts, where these species have been present in mixed populations with the common red spider. Experiments have not been conducted in the north-central portion of the state on walnuts where the Pacific mite evidently occurs on this host. However, laboratory tests indicate that this species is about as susceptible to *DN Dust* as is the common red spider. The material has no appreciable value against the walnut blister mite, which usually exists within galls in the leaves or within the buds.

The matter of application of *DN Dust* on walnuts is of considerable importance; however, it is not as difficult to obtain satisfactory coverage on walnuts as it is on citrus. It has been shown that the conventional dusting equipment employing a relatively small volume of air moving at a high velocity (approximately 2,000 to 3,000 cubic feet per minute at approximately 200 to 250 miles per hour) discharged through a 4- to 6-inch circular tube, manually operated, does not afford adequate coverage. The fan capacity previously indicated for citrus dusting equipment is entirely adequate for dusting the largest walnut trees, which in many instances are 50 to 60 feet in height. However, the "fish tail" type of discharge is not employed; instead, the "fish tail" assembly is replaced by an adapter suitable for walnut dusting. This adapter consists of a straight duct approximately 3 feet in length attached to the discharge of the fan in a horizontal position. It functions to allow the turbulent air at the discharge of the fan to become "straightened" and "flow" fairly uniformly before it reaches the outlet, where it is divided into two circular discharges and directed at the tree. Each discharge consists of a bellowed canvas tube approximately 2 feet in length, terminated by a circular metal attachment 16 inches in diameter, on which a convenient handle is placed and by which the operator manipulates the discharge in dusting a tree. The truck conveying the dusting equipment travels in the center space between two rows of trees at a rate of about 3 miles per hour, and each operator dusts the half of the tree that faces the equipment. One passage of the equipment is made in each center between two rows, so that all trees are dusted from two sides.

Walnuts are evidently fairly tolerant to *DN Dust*, since injury of economic importance has not occurred in tree-tolerance tests under extreme conditions. Certain plots comprising several varieties of walnuts received four applications with a very high dosage—about 10 pounds per tree at each application. The applications were purposely made the night preceding forecasted high temperatures. In all instances temperatures exceeding 100 degrees F. occurred and in one instance a temperature of 113 degrees F. was recorded.

In summarizing the work with *DN Dust* on walnuts, it appears that this material will afford satisfactory results in the control of the common red spider and promises to become of considerable value to the walnut grower.

DINITRO-O-CYCLOHEXYLPHENOL DUST ON PEACHES AND ALMONDS.—During the past two seasons several small-scale tests with dinitro-o-cyclohexylphenol in dust mixtures have been conducted on peaches and almonds infested with the common red spider and the clover mite. Good mortalities were obtained in all instances and no injury to the trees was observed. Although the data are meager and inconclusive, they suggest interesting possibilities for further work with this material in connection with the mite problems on these trees.

DINITRO-O-CYCLOHEXYLPHENOL DUST IN RELATION TO PUBLIC HEALTH.—The matter of the possible relation of dinitro-o-cyclohexylphenol to the health of men who prepare the dust and those who apply it in the field, and of the relation of residues on the fruit to the health of the consumer, has been considered. The first two authors and others have prepared and applied many tons of the dust mixture during a period of several years without any observed adverse effect. It is of in-

terest to note that with one of these individuals extensive exposure to the dust mixture for many hours nightly during application without a respirator or other such protection caused a negligible degree of discomfort, while with another individual a slight nasal irritation was evident. However, in the latter case this effect existed only during the period of exposure and was completely obviated through the use of the conventional respirator that employs felt or similar material as a filter. While respirators are provided for operators who apply the dust regularly under commercial conditions, many operators do not use them, alleging that such protection is apparently unnecessary. Nevertheless the exercise of ordinary precaution, at least the use of a respirator, in handling any insecticide or finely powdered material applied as dust is deemed essential.

Residues of dinitro-o-cyclohexylphenol applied in dust mixtures on citrus fruits are completely removed by the conventional alkaline washes and subsequent clear water sprays used in regular packing-house operations. Furthermore, the chemical rapidly dissipates on exposure to atmospheric conditions, and in most instances the dissipation is complete before the fruit is picked. There is no evidence to indicate that any of the compound penetrates the skin of dusted fruits.

A study of the relation of dinitro-o-cyclohexylphenol dust residues to public health has been conducted at the University of California Medical School. The following excerpts are taken from the summary of these studies (Hrenoff & Leake, 1939):

"So far as possible public health hazards may be involved in the use of 2-4-dinitro-6-cyclohexyl-phenol in pest control, feeding experiments with oranges from trees treated with the chemical are more significant than the direct estimations of the toxicity of the agent. These feeding experiments quite clearly indicate that there is no danger to consumers from fruits from trees dusted with preparations containing 1 per cent of the chemical. Field tests indicate that there is no injury to citrus trees, nor is there any untoward contamination of the soil with resulting absorption of toxic compounds by the trees.

"A possible hazard remains for workmen applying the dusts. They should be protected by gloves and masks, and should use respirators. They should also be required to restrict their use of their working clothes to this work only, and to wash thoroughly. It is well established that nitrated phenols are capable of being absorbed through the skin and respiratory mucous membranes. However, since more than one million pounds of the dusts have already been applied by unprotected workmen without untoward effect, these precautions may not be essential for safety."

SUMMARY.—The citrus red mite, *Paratetranychus citri* (McG.), is the most important mite pest on citrus and constitutes a problem in over 125,000 acres. A study of the relation of insecticides to the control of this mite has shown the need for a material other than petroleum oil to cope with the problem.

The common red spider, *Tetranychus telarius* (L.), is the most important mite pest on Persian walnuts, and an effective and relatively inexpensive method of control would be valuable.

The advantages of a dust insecticide in mite control are rapid application and low application costs. Climatic conditions in the citrus and walnut areas are favorable for the use of dust acaricides.

Dinitro-o-cyclohexylphenol is very toxic to mites when applied as a dust. Dust mixtures prepared by dispersing petroleum oil solutions of this compound in diatomaceous earth have given high initial mortalities of mites. Because of rapid dissipation and deleterious effects on citrus resulting from this oil type of dust, a dust mixture without oil has been developed.

Dinitro-o-cyclohexylphenol reacts with the basic principles of certain dust diluents to form salts. Certain evidence appeared to indicate that these salts were responsible for a variable and rapid loss of toxicity to mites. Since the ground flours of lignocellulosic materials do not react with dinitro-o-cyclohexylphenol to form salts, such materials were investigated as dust diluents. Walnut-shell flour and redwood-bark flour offered the most promise.

A more uniform dispersion of dinitro-o-cyclohexylphenol in the diluent was obtained by the solvent-mix method than by the mechanical or ball-mill method.

A study of dust diluents as related to weathering of dinitrc-o-cyclohexylphenol has shown that the rate of weathering is related to temperature. Under conditions of high temperature, dinitro-o-cyclohexylphenol dissipates more rapidly than under low temperature conditions. Sunlight and humidity are of little or no importance in weathering.

A deposit of 0.4 microgram per square centimeter of fruit surface of a 1 per cent dinitro-o-cyclohexylphenol–walnut-shell flour mixture is lethal to adult female citrus red mites. A laboratory toxicological method is described.

Field data have demonstrated that deposits of a 1 per cent dinitro-o-cyclohexylphenol–walnut-shell flour dust are much greater under conditions of high relative humidity than at low relative humidity. With exception of an application of 1 pound of dust per tree applied under low relative humidity conditions, lethal residual deposits were present on the leaf surfaces for a period of approximately 4 days under moderate temperature conditions.

As a result of an extensive field program in 1937, a properly prepared solvent-mix dust consisting of 1 per cent dinitro-o-cyclohexylphenol in walnut-shell flour gave promising results for control of the citrus red mite. Hence there developed a demand on the part of growers for this material. A proprietary product registered in California as *DN Dust* was made available for limited commercial usage in April, 1938. Over one million pounds have been applied commercially by the manufacturer under a wide variety of conditions.

Improved dusting equipment was devised to insure more thorough application of dust insecticides on citrus.

The dosage of *DN Dust* for a mature tree varies in accordance with the presence of fruits that are approximately one-half of full size or larger, the presence of moisture on the trees at the time of application and the density of tree foliage.

A dosage of 1 pound of *DN Dust* per tree when only young fruit is present appears adequate under most conditions. In the presence of larger fruit the dosage must be increased to 1½ or 2 pounds per tree. If moisture is present at the time of application, this dosage may be reduced by approximately 25 per cent. When the foliage is less dense, particularly in the case of lemons, the dosage must be increased. A program consisting of two properly synchronized applications is most dependable in effecting control, although one application has, in some localities, afforded very satisfactory control for periods of several months and longer.

It has been found that *DN Dust* can be used with comparative safety on citrus. The most important factor relating to injury appears to be the incidence of high temperatures occurring within a period of two days after application. By not applying the *DN Dust* when temperatures above 95 degrees F. are forecast, this injury has been of negligible economic importance.

A mixture composed of 1 per cent dinitro-o-cyclohexylphenol in redwood-bark flour has been used extensively and to date it appears to be equal in effectiveness to the standard mixture in which walnut-shell flour is used.

Dust mixtures containing 1 per cent dinitro-o-cyclohexylphenol in either walnut-shell flour or redwood-bark flour have been found to afford very satisfactory control of the common red spider, *Tetranychus telarius*, on Persian walnuts. A program consisting of one application of 3 pounds of dust per mature tree is apparently adequate. Injury of economic importance has not occurred in tree-tolerance tests under extreme conditions.

DN Dust has been used on peaches and almonds infested with common red spider and the clover mite, *Bryobia praetiosa* Koch, high mortalities having been obtained in all instances. No injury to the trees has been observed.

The matter of the relation of *DN Dust* to public health has been considered. There appears to be no significant public health hazard involved in the use of this preparation either to the operators who apply the dust or to the consumers of treated fruits.

ACKNOWLEDGMENTS.—Many individuals have contributed materially to this work. It is a pleasure to acknowledge the valuable aid of H. J. Quayle, C. O. Persing, F. G. McCarty, G. L. McCall, R. W. Underhill and B. Bartlett, Citrus Experiment Station, and of L. E. Mills of the Technical Research Department of The Dow Chemical Company.—5-8-39.

LITERATURE CITED

Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. JOUR. ECON. ENT. 18(2):265–7.

Boyce, A. M., and D. T. Prendergast. 1936. Dinitro-o-cyclohexylphenol offers promise in control of citrus red mite. JOUR. ECON. ENT. 29(1):218–9.

French, O. C. 1938. Dusting for control of citrus pests. Ag. Eng. 19(4):165–6, 169.

Hoskins, W. M., A. M. Boyce and J. F. Lamiman. 1938. The use of selenium for the control of mites on citrus and grapes. Hilgardia 12(2):115–75.

Hrenoff, A. K., and C. D. Leake. 1939. Toxicity studies on 2-4-dinitro-6-cyclohexylphenol, a new insecticide. Univ. Calif. Publ. Pharmacol. 1(12):151–60.

Kagy, J. F., and C. H. Richardson. 1936. Ovicidal and scalicidal properties of solutions of dinitro-o-cyclohexylphenol in petroleum oil. JOUR. ECON. ENT. 29(1):52–61.

SCIENTIFIC NOTES

Corrodentia as Pests of Ground Feed

Ground feed stored at ordinary room temperatures was found to be infested by Corrodentia which were identified by A. B. Gurney as *Troctes divinatorius* (Müll.). Feed so infested consisted of samples sent to the Maine Agricultural Experiment Station from various parts of the state for analysis.

The insects, so small as to be easily overlooked, occurred in countless numbers in many of the samples. Both nymphs and adults were present and very active at room temperatures. Tunnels or runways through the feed materials could be seen against the sides of the glass containers in which the feed samples were stored.

Sealed glass jars of 1 pint capacity were used for storing the feed and every care was taken to prevent infestation by insects after the feed samples were received. It seems evident therefore that infestation of the feed by Corrodentia must have occurred previous to the receiving of the samples and it is probable that these insects infest ground feed in the several localities in the state from which the feed samples were received.—3-6-39.

JOHN HAWKINS, *Maine Agricultural Experiment Station, Orono.*

Introduced Pine Sawfly

The introduced pine sawfly, *Acantholyda erythrocephala* (L.), is a pine-leaf-feeding sawfly widely distributed in Europe and also recorded from Chosen and Japan. In these countries it is reported as injurious to various species of *Pinus*, occasionally occurring in serious outbreak form, and is also reputed to attack *Larix*, *Picea* and *Abies*.

It was first found in North America in 1925, when two male adults were taken at Chestnut Hill, Pa. No record of its occurrence appeared again until 1936, when the species was found attacking white pine in Morris and Somerset Counties, N. J. In 1937 the species was found defoliating a 1½-acre stand of red pine in Bergen County, N. J. Since then the sawfly has been found to be widely distributed throughout the northern half of New Jersey, occurring also in Rockland and Orange Counties, N. Y., and in Monroe, Northampton and Bucks counties, Pa. Members of the Department of Agriculture of the State of New Jersey and the Conservation Department of the State of New York, working under the direction of H. B. Weiss and H. L. McIntyre, respectively, have assisted in scouting for the insect. Most of the distribution records are based on determinations made by the writer from larvae and prepupae.

In this country the larvae of this sawfly have been found feeding on red pine (*Pinus resinosa*), white pine (*P. strobus*), mugho pine (*P. mughus*), Swiss Mountain pine (*P. montana*), Scotch pine (*P. sylvestris*), Japanese red pine (*P. densiflora*) and Austrian pine (*P. austriaca*). Red pine and white pine appear to be the most favored and Austrian pine the least. Although reported as attacking *Larix*, *Picea* and *Abies* in Europe, the sawfly has not yet been found to do so in this country despite the close proximity of trees of these genera to an area heavily infested by *Acantholyda erythrocephala*.

This sawfly is quite different in appearance from most species of sawflies commonly found on pines. The adults range from 9 to 13 millimeters in length and have long, threadlike antennae typical of the family Pamphiliidae to which this species belongs. They are deep steel blue with the following exceptions: Anterior tibiae and apices of anterior femora ochreous; head of female, except interocellar area, orange; lower half of face of male, as well as mandibles and mouthparts, ochreous. The egg is about 2.75 millimeters in length, elongate-oval in shape and yellow in color, changing to brown as incubation advances. Like all pamphiliid larvae, as compared with the larvae of most sawflies, that of *Acantholyda erythrocephala* has unusually long, slender 7-jointed antennae, unusually weak and slender legs, a pair of slender 3-jointed appendages on the last abdominal segment, and lacks prolegs but has a pair of fleshy protuberances resembling larvapods on the venter of the eighth abdominal segment.

The mature larva is 16 to 20 millimeters in length and pale greenish gray in color with longitudinal mid-dorsal, lateral and mid-ventral stripes of purplish red. The head is of a clay-yellow color with dense, small spots of dark brown above, and black eyes. The prepupa is apple green with a longitudinal mid-dorsal line of dark green, and the pupa is green with black eyes.

Acantholyda erythrocephala has one generation annually in New Jersey. The adults emerge from their earthen cells from mid-April till early in May, the females usually laying their eggs contiguously in rows of from 3 to 10 on the flattened surface of the pine needles of the previous year's growth. The female cuts small slits in the needles and over these the eggs are laid, but only a very small section of the egg resembling a crease is inserted. The incubation period is about 22 days and hatching occurs during the last 3 weeks in May. After hatching, the larvae

descend the needles to the stem, there spinning a loose webbing about themselves by attaching their silken threads to the basal region of the needles. Within this covering the first-instar larvae sever the needles just above the bundle sheaths and feed gregariously at the bases, pulling the needles into the webbing as feeding progresses until the needles are entirely consumed. In the later instars the larvae spin individual silken tubes about themselves along the stem, to the outside of which a considerable amount of frass and needle fragments has been woven. The larvae feed for a period of about 18 or 20 days and may be found from early in May till late in June. When fully grown the larvae drop to the ground, entering it to a depth of about 2 or 3 inches, and fashion earthen cells (instead of the usual type of sawfly cocoon), in which they spend the summer, fall and winter as prepupae. Pupation occurs late in March and early in April of the following spring. —3-13-39.

C. L. GRISWOLD, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

Observations on the Potato Psyllid in Southwest Texas

During the past two years observations have been made on the seasonal activities and extent of damage caused by the potato psyllid, *Paratrioza cockerelli* (Sulc), in southwest Texas. The insects were found widely distributed on tomato plants in Maverick, Dimmit, Zavala and Webb counties in the fall of 1936 (Janes 1937) and since that time have occurred on tomatoes whenever this crop has been grown. Injury in general on tomatoes, however, has been comparatively light with only localized seedbeds or fields being severely infested. Injury to Irish potatoes on the other hand has been severe. During the spring of 1938 every planting examined at Carrizo Springs was heavily infested with psyllids. "Psyllid yellows," the disease for which these insects are responsible, was very much in evidence and in some fields 100 per cent of the plants were severely affected. In the later cases the crops were a total loss. The insects were also found on eggplants and peppers, in low numbers. Dry lime sulfur spray and sulfur dust gave promising results in preliminary tests on control.

Three important native host plants of *Paratrioza cockerelli* were observed during 1938. The plants are as follows: *Lycium carolinianum* Walt., var. *quadrifidum* (Moc. & Sesse ex Dunal) C. L. Hitchc., *Physalis mollis* Nutt. and *Solanum triquetrum* Cav.* *P. mollis* is widespread and abundant, occurring in cultivated areas and on land still covered with native brush. Psyllids were found on these plants whenever examinations were made; they often occurred in abundance. These native host plants make possible a considerable survival of the psyllids from season to season.—3-18-39.

M. J. JANES, *Texas Agricultural Experiment Station, Alta Loma.*

LITERATURE CITED

Janes, M. J. 1937. *Paratrioza cockerelli* (Sulc) on tomatoes in southwest Texas. JOUR. ECON. ENT. 30(2):379 (sci. note).

* Determinations by V. L. Cory, Texas Agricultural Experiment Station.

Notes on the Biology and Control of the Greenhouse Stone Cricket

The greenhouse stone cricket, *Tachycines asynamorus* Adel., an introduced Asiatic species appears to have widespread distribution in this and other countries of the world. It is reported mainly as a pest in greenhouses in Germany, Russia, Great Britain, France, Norway and the United States.

In this country, it is reported largely from some of the New England and north central states. A report of its occurrence in Colorado appears to be the western extent of its known distribution in the United States.

The cricket, being nocturnal in its habits, usually occurs in a greenhouse for some time before being noticed. During the day time it hides away, in cracks and crevices, from the light. These crickets have been reported as feeding upon tomato, lobelia, begonia, cyclamen, petunia, nicotiana, gloxinia, chrysanthemum and cucumbers besides insects and crustaceans.

In a greenhouse at the North Dakota Experiment Station, where an infestation developed, the main injury done by the crickets was to flax seedlings. The injury consisted mainly of their eating the cotyledons shortly after the plant had emerged from the soil. After the plants were a week to 10 days old they were no longer subject to attack from these insects.

Crickets were maintained in cages under greenhouse conditions to secure data on their biology and habits. They fed readily upon flies and pillbugs, when these were put in the cages. Cannibalism occurred when several of the crickets occupied the same cage. Usually they fed upon the crippled, molting or an otherwise helpless cricket.

The eggs are white, eliptical in shape and average about 2.2 millimeters long by 1.1 millimeters wide. The eggs were normally deposited at a depth of about one-fourth inch in the soil on the floor of the cage and required from 8 to 12 weeks incubation period under greenhouse conditions. The egg laying rate of females under observation ranged from 3 to 18 eggs per night, for a period of about 5 weeks.

The newly emerged nymphs assumed a black, shiny appearance, but became more of a brownish gray color with later development. The young insects appeared to feed as readily as the older stages on plant seedlings. There was overlapping of generations under greenhouse conditions, with new broods appearing at all seasons of the year.

Most satisfactory control was obtained by the use of a bait made of sodium fluosilicate 10 per cent and ground beef (hamburger) 90 per cent (by weight). This bait resulted in 80 per cent control of the crickets, in the course of 4 days after its application, where the insects were maintained in cages along with seedling hosts plants. There was no mortality in the control cages supplied only with unpoisoned ground beef plus the seedling host plants. While the method may require further testing, it would appear that this poisoned ground beef bait is worthy of further trial for destroying greenhouse infestations. It is suggested that the bait be applied in small quantities in places accessible only to the crickets. Arsenicals used as poisoning agents appeared to have a repelling effect on the crickets. Poison bran bait with either the fluorine or arsenicals were of no value.—3-22-39.

I. G. BUE and J. A. MUNRO, *North Dakota Agricultural College, Fargo.*

New Mosquito Records from Key West, Fla.

Culex bahamensis Dyar & Knab, a species of mosquito heretofore known only from certain islands of the West Indies, has been found to be fairly common at Key West, Fla. Larvae of this species were first discovered in an abandoned brackish cistern, in company with *Anopheles atropos* Dyar & Knab, on January 24, 1939, by Richard Belt and Harold G. Walker, inspectors of the *Aedes aegypti* Control Unit, United States Public Health Service. Since that time other breeding places have been located, and the adults have been taken regularly with light traps.

The writer's identification of this species, as well as that of the *Anopheles atropos*, was confirmed by Dr. W. V. King at Orlando, Fla. Dr. King also suggested that this might account for the single United States record of "*Culex corniger*" from Knight's Key in 1908, since females of the two species are described as being very similar. Extensive surveys in Miami and environs have failed to show the presence of *Culex bahamensis* there. This would indicate that its United States distribution is limited to the Florida Keys.

The discovery of *Anopheles atropos* is interesting as it is the first anopheline recorded from Key West since the discovery and apparent eradiction of *Anopheles albimanus* Weid. from the island in 1904. Only one breeding place, other than the one mentioned above, has been discovered. No adults have been taken.—3-24-39.

FRANK W. FISK, *U. S. Public Health Service*, Aedes aegypti *Control Unit.*

Cryolite Dips as a Control Measure for the Corn Root Webworm on Newly Set Tobacco Plants

The corn root webworm, *Crambus caliginosellus* Clem., often causes severe losses of newly set tobacco plants in north central Tennessee. In preliminary field experiments conducted at Clarksville in the spring of 1938 it was found that such losses could be reduced by dipping the plants in cryolite mixtures. These mixtures consisted of cryolite and water used alone and in combination with each of the following supplements: Fish oil, animal glue, bill-posters' paste and mineral oil. Three ounces of cryolite (containing 85 per cent of sodium fluoaluminate) were used per gallon of water.

The plants were dipped just before being set out in the field. In one experiment the entire plant was dipped and in a second only the root and stem. Dark fire-cured tobacco plants were used in both experiments. The plants in each experiment were set out in 36 one-fortieth-acre plots of 100 plants each arranged in a Latin square, making 6 replicates for each of the 6 treatments.

Experiment 1 was conducted on May 9, when the moixture content of the soil was high and the air temperature approximately 65 degrees F., and experiment 2 on May 14, under approximately the same conditions. Light rains fell soon after the plants were set.

A few of the severely injured plants in experiment 1 remained alive and erect during a rainy period of 21 days following transplanting, but when the top soil became dry these plants were unable to survive. Had the transplanting been followed immediately by several days of dry weather the total crambid damage would have been evident in less than 14 days. Experiment 2 was discontinued after 14 days. The data for both experiments are presented in table 1.

Table 1.—Survival of tobacco plants 14 days after being dipped in cryolite mixtures and transplanted, Clarksville, Tenn., 1938.

Accessory Material	Quantity of Supplement Per Gallon of Water	Ounces of Cryolite Per Gallon of Water	Percentage of Plants Surviving*
	Entire Plant Dipped		
Fish oil	15 cc.	3	85
Animal glue	0.5 oz.	3	87
Bill-posters' paste	1 oz.	3	86
Mineral oil	15 cc.	3	84
None	0	3	81
None	0	0	33
	Stem and Root Dipped		
Fish oil	20 cc.	4	76
Animal glue	20 gm.	4	84
Bill-posters' paste	1.5 oz.	4	77
Linseed oil	20 cc.	4	76
None	0	4	87
None	0	0	31

* Statistical analyses show that there are no significant differences attributable to the supplements.

These tests were so limited in scope that no conclusions can be drawn from them, but it is believed that they offer a good lead in working out a satisfactory control for crambids and perhaps other insects affecting young tobacco plants.

Under the weather conditions existing when this work was done these treatments were noninjurious to the plants, but they should not be recommended for general use until they have been tested under all weather conditions.—3-27-39.

L. B. SCOTT and JOE MILAM, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

Transmission of the Narcissus Mosaic Virus by Aphids

The disease now known as mosaic disease of narcissus was demonstratd by McWhorter (1932) to be caused by a virus. Up to the present time there has been no satisfactory explanation regarding the manner in which the virus is disseminated under natural conditions. It is the purpose of this paper therefore, to report four species of aphids as vectors of the virus.

Transmission studies have been conducted on Long Island, N. Y., over a period of four years, and during this time 1,495 healthy narcissi have been exposed to inoculation by aphids taken from foliage of narcissi showing mosaic symptoms or confined in cages containing both mosaic and healthy plants. Of the various species tested the percentages of transmission are as follows: *Aphis rumicis* L., 66; *Illinoia solanifolii* (Ashm.), 36; *Marcosiphum rosae* (L.), 65; and *Myzus convolvuli* (Kalt.), 65.

Specimens from each type colony of the aphids used in the transmission studies have been identified by P. W. Mason and all species except *Illinoia solanifolii* (Ashm.) are preserved in the United States National Museum at Washington, D. C., under the following numbers: *Aphis rumicis* L. T. C. no. 6631, *Marcosiphum rosae* (L.) T. C. no. 6632, and *Myzus convolvuli* (Kalt.) T. C. no. 6643.—4-3-39.

F. S. BLANTON, *U. S. Department of Agriculture,*

Bureau of Entomology and Plant Quarantine, and F. A. HAASIS, *Cornell University, Ithaca, N. Y.*

LITERATURE CITED

McWhorter, F. P. 1932. Narcissus "gray disease" is a transmissible mosaic. Florists Exch. and Hort. Trade World 79(14):11. 2 figs.

Distances Traveled by Newly Hatched Codling Moth Larvae

Observations near Vincennes, Ind., have indicated that newly hatched codling moth larvae may find and infest apples growing on the tree at considerable distances from the point of hatch.

Preliminary experiments to gain information on this matter were carried on in an orchard near Vincennes the latter part of August, 1938. During this period native moth activity in this particular orchard was at a very low level and practically no eggs were being laid. On an average less than 1 egg per 100 bearing spurs per day was being deposited. An 8- by 14-inch screen sleeve cage, containing 200 moths, was placed over a low-hanging branch on each of four trees. One tree had been sprayed with lead arsenate and weak Bordeaux mixture, another with phenothiazine and a third with tank-mixed nicotine sulfate–bentonite–soybean oil. The fourth tree was left unsprayed. They were of the Ben Davis variety and were about 35 years old. They retained at least 1,500 apples each at the time of the experiments, and had received their final cover spray on August 2.

Eggs deposited on foliage and fruit in the cages on August 15 and 16 were counted and allowed to hatch. Hatching began on August 21 and was 90 per cent complete by August 24, when careful examinations were made. During the hatching period temperatures were normal and no rains or high winds occurred.

Close inspection of the foliage within a few feet of the cages failed to reveal any eggs from which the larvae could have hatched, thus eliminating the possibility that native moths might have been attracted to the vicinity of the cages.

On the unsprayed tree approximately 1,825 eggs were deposited on foliage and fruit in the cage. All apples within 5 feet of the point of hatch were infested with newly hatched larvae. Many fresh injuries were found between 5 and 10 feet away, but none on the opposite side of the tree, and a superficial examination did not show any on adjacent trees. Some apples 2 feet from the point of hatch contained as many as 65 injuries and apples 3 to 5 feet away contained 1 to 10.

On the tree sprayed with lead arsenate and Bordeaux mixture, 913 eggs were deposited in the cage. No newly hatched larvae were found in fruit more than 5 feet from the point of hatch. One apple 3½ feet away contained 42 injuries and many apples within 5 feet contained 1 to 5. On the tree sprayed with phenothiazine 667 eggs were deposited. No fresh injuries were found beyond 6 feet, but as many as 23 were found on single apples 4 feet away and 20 on apples 5 feet away. On the tree sprayed with nicotine sulfate–bentonite–soybean oil 600 eggs were deposited, but very few injuries were found and none of them was more than 2 feet away.

Larvae may have been blown by wind currents on to limbs other than those on which the eggs were laid, thus causing some of the many injuries found on those limbs.

These experiments indicate that in the absence of spray deposits larvae may find and enter apples as far as 10 feet from the point of hatch, but the presence of spray deposits on the foliage apparently causes many larvae to die before they travel as far as they would on unsprayed trees.—4-22-39.

L. F. STEINER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

Fixation Method for Distinguishing Dead and Live Black Scale on Citrus

An investigation to develop a satisfactory method for field evaluation of materials for the control of the black scale, *Saissetia oleae* (Bern.), has shown the necessity for a better criterion or method for distinguishing between the dead and live scale insects. The customary procedure has been to allow a sufficient lapse of time after application of treatments for desiccation of the dead insects and to characterize the live insects by general appearance and nature of the blood when the scale are ruptured with a needle. The doubtful or borderline cases are by no means few. This fact, together with the problem of dirt and fungi on the leaves, has necessitated puncturing nearly all insects that are not entirely dry before a decision can be reached. In addition to the fact that this method is very slow and tedious, much error has probably resulted from differences of opinion in regard to whether a black scale insect is dead or alive. Observation of appendage movement as a criterion for distinguishing live scale is impractical.

Fixation of immature black scale on orange leaves in acetic acid vapor prior to making scale counts proved to be a very effective means for distinguishing the live scale and has been employed successfully for the past two seasons.

The following technique for fixing the live scale was found to be satisfactory. A steel drum with a tight fitting cover interiorly coated with beeswax to prevent corrosion is used as a fixing chamber. Two holes are cut in the side of the drum, one near the top and the other near the bottom. A distilling flask containing glacial acetic acid is attached to the top hole. Scale infested leaf-samples in containers are placed in the drum, after which it is closed. Acetic vapor is then distilled into the drum for a period of approximately 5 minutes. This treatment is sufficient to insure a supersaturated atmosphere with a slight amount of condensation on the leaves. The scale infested leaves are allowed to remain in the acetic acid vapor for a minimum of 3 hours to insure fixation of all live scale, after which the leaves are removed and dried before being counted.

By this process of fixation, the live immature black scale are bleached from an oxidized or brown to a light yellow or amber color. As a result they are more readily visible on leaves heavily covered with fungi and can be distinguished from the dead scale with greater speed and accuracy. The appearance of dead scale is apparently unaffected by acetic acid vapor, and the contrast between dead and fixed scale is sufficiently great to obviate rupturing. Borderline cases are infrequent; consequently, the error in determining live scale is considerably reduced.—5-1-39.

J. F. KAGY, C. O. PERSING and K. E. MAXWELL, *University of California Citrus Experiment Station, Riverside.*

JOURNAL OF ECONOMIC ENTOMOLOGY

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Cooperation In Scientific Work

COOPERATION has been a word of many meanings. It has at times meant a sincere effort to accomplish something of mutual good. At other times it has been a mere empty word implying little or nothing of a concrete nature. Too often it has meant an effort of advantage to only one of the cooperators. In scientific endeavor, cooperation ought to signify working together to solve some of the problems of humanity. This type of cooperation is exemplified by an organization known as the Western Cooperative Spray Project. Peculiarly a product of the West, this organization was formed in 1926 at a conference of chemists and entomologists called by Dr. J. R. Parker, then of the Montana Agricultural Experiment Station. It has since developed into a group of over 50 members, including not only chemists and entomologists, but also horticulturists, plant pathologists and physiologists.

Its purpose is to effect a real and lasting cooperation among these members in developing new and better methods of spraying fruit trees for controlling insects and diseases, "with the particular objects of advancing more rapidly our knowledge of spray materials and their use; of bringing about the use of uniform materials and methods in experimental spraying, in order that results secured in one district may be more accurately compared with those secured in other regions; of broadening the knowledge of individual workers by the exchange of ideas and a discussion of the work that has been accomplished; of establishing mutual confidence; and of avoiding trespass in matters of credit."

Its authority is an official Memorandum of Understanding, from which the above quotation has been taken, signed by the directors and chiefs of the various agencies included in the project, and approved by the Office of Experiment Stations.

Its accomplishments are many. Formed for the purpose of coordinating the rapid development of oil as an insecticide, this project had a major part in standardizing oil sprays. It has also had a steadying and regulating influence on the development and use of other spray materials. It makes no recommendations, but its findings, based on the evidence of coordinated experimental work done by its members, constitute the basis of all official spray recommendations made in the Pacific Northwest. They influence, too, those made by private groups. It has standardzed to an important extent the methods of experimentation with sprays and the means of presenting results. Although diplomacy is not a part of its official purpose, the project has maintained most cordial relations with the insecticide and fungicide industries, to the mutual advantage of all.

These accomplishments have come about through the whole-hearted and enthusiastic cooperation of the members. They have been made possible by men who, after attending a conference all day, are willing to sit up half the night on committee assignments making plans for the project, by men who can forget personal ambition for the general welfare. They contrast strongly with many of the disturbing events in the world of today. They constitute one evidence of the value of civilization. Scientists elsewhere, to use the English phrase, "could do worse" than to study and make use of the methods and accomplishments of this group. —4-27-39.

E. J. NEWCOMER

REVIEWS

A Contribution to the Biology of North American Vespine Wasps, by Carl D. Duncan, Professor of Entomology and Botany, San José State College, California. Stanford University Publications, Biological Sciences, Vol. VIII, No. 1, 1939, 272 pp., pls. I–LIV. Stanford University, California. Price, paper $2.50, cloth $3.25.

The curiosity that prompted the bear in the song to go over the mountain to see what he could see has its counterpart in the mind of every entomologist. From courses of study, textbooks and an occasional article that comes to our attention, we formulate a conception of the way this or that group or species of insects lives. But upon reflecting, we are bound to acknowledge that our information is fragmentary or incomplete, and we find ourselves wondering what is the complete story, or wish we might at least be able to acquire what investigators have, so far, made known. It is, therefore, a very satisfactory treat to find the facts, heretofore scattered in hundreds of papers, assembled and organized into something approaching a complete picture by one who has become the master of his subject. And the gratification is all the keener when the treatise concerns so intriguing a group of insects as the vespine wasps.

Professor Duncan has produced this work out of 20 years of personal investigation into the morphology, systematics and particularly the bionomics of this subfamily of Vespidae. While the writer has not attempted to review the literature of wasp biology exhaustively, he has cited 168 articles and embodied their essential facts in his contribution. This large body of information is further made accessible by a generous index of 16 pages, and is liberally illustrated with 54 full-page plates. Plates I–XXXII consist of excellent, well-spaced line drawings of good size, fully depicting the external morphology and muscles of the adult queen and male of *Vespula pennsylvanica*. Plate XXXIII diagrams the lobed nests of *V. pennsylvanica* built in two types of ground, while plates XXXIV–LIV are splendid photographs, showing shapes, attachments and both external and internal construction of the paper nests of several species.

The verbal part of the treatise is divided into four sections: introduction, morphology, systematics and biology. The Vespinae now inhabiting North America belong to the three genera *Vespa*, represented only by the European hornet species *crabro* L.; *Dolichovespula*, which includes the white-faced hornet, certain yellow jackets and some wasps of other coloration, and *Vespula*, consisting mostly of typical yellow jackets. Characters of the genera are given.

Part II, 71 pages in length, is an original study of the morphology of *Vespula pennsylvanica* (Sauss.). Most of the space is devoted to the anatomy of the queen, followed by brief descriptions of the worker and male. Of the internal structures, only the musculature is treated in full.

The taxonomic section is limited to 12 pages. After the characteristics of the subfamily Vespinae follow the structural and biological characters of the three genera named above.

The remaining 78 pages of the discussion treat the bionomics of the subfamily. While this division contains liberal quotations, fully credited, from the studies of earlier investigators, it offers very much that is new from the researches of the writer. In the course of his studies, which extended more or less continuously over the past 20 years, the writer made numerous observations in the field, both on individual wasps and on active colonies. Many colonies were collected in their entirety, and a careful census was made of their contents. The field work has been supplemented by laboratory studies. *Vespa crabro* usually nests in hollow trees, and with rare exceptions the species of *Dolichovespula* choose aerial sites for their nests, while the members of *Vespula* are typically subterranean in nesting habit. Most of the species of the subfamily exhibit three well-defined castes—male, queens and workers—but both *Vespula* and *Dolichovespula* contain parasitic forms which have no worker caste. The major bionomic topics discussed are seasonal history of a wasp colony, hibernation, foods and feeding behavior of both adults and larvae, building activities, and life history and metamorphosis.

This volume thus combines a digest of much previously published knowledge verified and greatly extended by the very valuable and interesting researches carried on by the writer. One of its laudable features is the combination of anatomical, systematic and bionomic aspects to form a unit study or complete picture. One hungers for similar balanced comprehensive works covering such other groups as the sphecoid, ichneumonoid, chalcidoid and other hymenopterous groups which bear so weightily and directly upon insect control, and grip our attention by their fascinating bionomics. Since the object of scientific studies is generalization, Professor Duncan has advanced our science a long step toward that goal in the field of Vespine biology. —3-21-39.

W. V. Balduf, *University of Illinois, Urbana.*

Field Crop Entomology, by Don B. Whelan. 55 pp., illus. 1938. John Swift & Co., Chicago. Price $1.00, net.

This book is arranged in the form of a handy reference field handbook, planographed in clear type on one side of sheets 6 by 9 inches, with the printed matter extending across the paper. The author has enhanced the value of the contents of the book by illustrating each insect with an original drawing or with sketches taken from publications of various writers on economic entomology.

The book is intended to furnish sufficient information regarding the description, life history, injury, food habits, distribution and the control of insects to serve as an aid to teachers of vocational agriculture and county agents in identifying field crop insects with which they come in contact. It is not intended to be an exhaustive treatise on the biology and life economy of an insect. The sheets are bound loosely with three removable brads so that information on new pests could be typed on a page of the same size as those in the book, inserted, and thus adapt the book to the needs of a worker in a given community.

The general discussions on insect distribution, insect growth, development and control are clearly stated, accurately presented and interestingly illustrated. If additional pages are desired for use as enclosures in letters, they may be secured in numbers of hundreds or thousands by writing to the publishers.

The insects considered are those of chief concern to workers in the corn belt states. Some space could have been conserved on a number of pages by placing the headings at the side of the page in bold face type rather than in the center of the page. This would have saved space for descriptive material.

The book may be purchased from the author or from the University of Nebraska, Lincoln.—3-27-39.

HARRY R. BRYSON, *Kansas State College, Manhattan.*

CURRENT NOTES

NORTH CENTRAL STATES ENTOMOLOGISTS

One hundred forty persons registered at the Hotel Lowry, St. Paul, Minn., for the annual meeting of the North Central States Entomologists, March 23 and 24. They came from as far east as Washington, D. C., as far south as Oklahoma and as far west as North Dakota. Two general sessions and six sectional meetings were held. Ninety-five attended the banquet when the Ukranian Ballet and Chorus of the Twin Cities entertained. The Friday afternoon general session was held at University Farm where the visitors later spent some time visiting the entomological quarters.

Professor A. G. Ruggles acted as chairman of the conference. Among the speakers were R. A. Trovatten, C. J. Drake, R. H. Nagel, A. C. Hodson, R. H. Painter, Ray Hutson, S. C. Chandler, A. A. Granovsky, E. M. Searls, P. N. Annand, G. A. Dean, J. R. Parker, John Medler, John H. Lilly, H. A. Henman, Fred Morton, Robert E. Shotwell, George Decker, B. M. Gaddis, Claude Wakeland, W. E. Dove, T. R. Chamberlain, C. L. Fluke, W. P. Flint, W. P. Hayes, C. M. Packard, C. L. Metcalf, J. J. Davis, J. A. Athelstan, R. T. Cotton, W. E. McCauley, H. H. Shepard, O. W. Park, Harry Laidlaw, H. F. Wilson, P. B. Paddock, J. A. Munro, M. H. Haydak, R. L. Parker, H. J. MacAloney, Lloyd Peterson, W. L. Boyd, R. Fenstermacher, G. D. Jones, F. G. Butcher and W. A. Riley.

The 1940 conference will be held at Purdue University, Lafayette, Ind.

CENTRAL PLANT BOARD MEETING

The Annual Meeting of the Central Plant Board was held in the Hotel Lowry, St. Paul, Minn., March 21 and 22. J. Carl Dawson was elected President and P. T. Ulman, Secretary.

PEST CONTROL NEWS

Professor H. H. Shepard of the University of Minnesota was recently elected an honorary member of the Northwest Pest Control Association.

Professors W. B. Herms of the University of California and J. J. Davis of Purdue University were elected honorary members of the California Pest Control Association at a meeting in Berkeley recently.

RILEY ENTOMOLOGICAL SOCIETY DINNER

The Riley Entomological Society of the University of Missouri held its annual dinner, Friday, March 31. Dr. C. L. Metcalf of the University of Illinois was the principal speaker.

THOMAS SAY SOCIETY DINNER

The Thomas Say Entomological Society of Purdue University held its annual dinner March 27. M. P. Jones of the U. S. Department of Agriculture, Bureau of Entomology, was the principal speaker.

CHAPMAN TO MINNESOTA

Dr. Royal N. Chapman, who since 1930 has been director of the experiment station of the Pineapple Producers Cooperative Association of Honolulu, has been appointed dean of the Graduate School of the University of Minnesota. Dr. Chapman was formerly a member of the faculty at University Farm, where he served as head of the division of entomology and economic zoology. He succeeds Dr. Guy Stanton Ford, newly elected president of the university, who was dean of the school from 1913 until his election last autumn. Dr. W. S. Miller, professor of educational psychology, has been acting graduate dean for the past two years. Dr. Gerald T. Evans, now assistant professor of biochemistry at Yale University, has been appointed director of the chemical-metabolic laboratories in the Medical School and the University Hospital. This appointment gives him the rank of associate professor of medicine. Dr. Chapman went to Hawaii in 1930 when the pineapple plantations there were threatened with serious insect damage.

ANNAND ASSISTANT CHIEF

Dr. P. N. Annand has been appointed assistant chief of the Bureau of Entomology and Plant Quarantine of the U. S. Department of Agriculture, effective April 1. Since September, 1937, he has been a special assistant to the chief of the bureau on matters relating to research. He will continue to give special attention to the integration and planning of the research work.

THE PUGET SOUND ENTOMOLOGICAL SOCIETY

Entomological workers in western Washington gathered at the University of Washington, Seattle, on Friday, March 10, 1939, and organized the Puget Sound Entomological Society. The objectives of the society are to promote the study of insects, arachnids and terrestrial arthropods in western Washington, and to promote the mutual welfare of the members through the exchange of ideas at meetings and field trips. Membership is open to persons of good character who are engaged in entomological activities. The society will hold two regular meetings annually, in February and October, the precise time and place to be determined by the executive committee which is composed of three elective

officers. The present officers are Professor Trevor Kincaid, University of Washington, President; Mr. S. E. Crumb, Entomologist, Bureau of Entomology and Plant Quarantine, Vice President, and Dr. E. P. Breakey, Entomologist, Western Washington Experiment Station, Secretary-Treasurer. Special meetings may be called by the executive committee at such time and place as it may determine.

The organization of the Puget Sound Entomological Society was the result of a movement initiated in the fall of 1938 by Dr. Breakey. Thirty-two persons with entomological interests, both professional and hobby, gathered in Puyallup on November 18, 1938. Many spent the afternoon visiting the Western Washington Experiment Station, and the U. S. Bureau of Entomology and Plant Quarantine field stations in Puyallup and Sumner. In the evening the group gathered for dinner, after which a discussion was held on the desirability of forming a permanent organization. Dr. Breakey was elected provisional chairman and Charles F. Doucette, Bureau of Entomology and Plant Quarantine, Sumner, provisional secretary. The chairman appoint a committee on organization: Professor Melville H. Hatch, University of Washington, chairman, to present a constitution and by-laws for discussion and approval at the next meeting. A nominating committee, W. W. Baker, Bureau of Entomology and Plant Quarantine, chairman, was also appointed.

The October meeting is to be held in Puyallup. A program is being formulated and some good papers are anticipated by the members.

Pest Control Laboratory at New York World's Fair

Some of the essential equipment of a typical pest control laboratory is being operated at the E. I. du Pont de Nemours Company's exhibit at the New York World's Fair. This laboratory forms part of that group of exhibits in the du Pont Building designed to illustrate laboratory control methods in use in applied research.

Experimental spraying of plants are demonstrated by the standard turntable method and sprayed and unsprayed plants in feeding cages are exposed to several kinds of the more common and injurious leaf-eating insects. A reduced model of a *Peet-Grady* lethal chamber is operated to show the method of developing and evaluating more efficient household insecticides. Several common insect pests are shown imbedded in *Lucite* discs, the face of these being convex so as to give an appreciable magnification.

Cultures of fungi which cause some of the more destructive seed-borne, soil-infesting and wood-rot diseases are on exhibit in connection with specimens illustrating the benefits of proper treatments. In conjunction with wood treatments it is also planned to maintain a large termite colony.

Appropriate lectures are given at frequent intervals to point out the necessity and value of pest control and to explain the operations of the laboratory methods demonstrated.

It is believed by persons familiar with the project that an interesting and spectacular feature of this exhibit is the recording of the feeding sounds of such insects as Japanese beetles, Mexican bean beetles and army worms amplified about 100,000 times.

A cordial invitation is extended by the company to all entomologists, plant pathologists and others interested in the control of insects and plant diseases to visit the du Pont Building when they attend the fair. Dr. M. D. Leonard has charge of the operations of the pest control exhibit and is on hand to answer questions.

Rocky Mountain Conference of Entomologists

The fifteenth Rocky Mountain Conference of Entomologists will be held at the University of Colorado Science Lodge, August 13 to 18, 1939. This Lodge is located in the Roosevelt National Forest about 25 miles west of Boulder and 65 miles south and west of Fort Collins, Colo., at an altitude of approximately 9,300 feet. The arrangements are such that all members of the families of the entomologists may enjoy an outing during the meeting. Comfortable bunk houses and cabins for sleeping will be available. Meals and bedding will be furnished at a reasonable cost.

At least 2 days of the meeting will be devoted to a discussion of forest entomology. This seems appropriate as forest insect problems exist in the immediate vicinity. The presence of many of the leading forest entomologists seems to be assured and a comprehensive survey of this phase of work is anticipated.

George M. List, Colorado State College, Fort Collins, Colo., is Secretary of the Conference and can provide further information on the meeting.

Friend Named Connecticut State Entomologist

Dr. Roger B. Friend has recently been appointed Connecticut State Entomologist and head of the Entomology Department of the Agricultural Experiment Station at New Haven, Conn. Dr. Friend is the second entomologist to hold this post. He succeeds the late Dr. W. E. Britton, who was State Entomologist from 1901 until his death in February.

Dr. Friend, until his appointment, was Associate Entomologist at the Connecticut Experiment Station. He was also Assistant Professor of Forest Entomology at Yale University.

Dr. Friend is a native of Massachusetts. He served in France during the World War. In 1923 he was granted a Bachelor of Science degree by Massachusetts State College. The following summer he worked as Assistant Entomologist on the Conservation Commission in New York State under Dr. E. P. Felt, then State Entomologist of New York. He entered the Graduate School at Yale University in 1924.

He received his doctor's degree at Yale in 1927 and became Assistant and later Associate Entomologist at the Connecticut Experiment Station.

Forest insects are Dr. Friend's chief field of concentration in entomology. He has compiled, edited and contributed sections of the "Diptera of Connecticut," a publication of the State Geological and Natural History Survey.

Dr. Friend is author of many scientific articles, bulletins and circulars which include the following: "Biology of the Birch Leaf Skeletonizer," "The Asiatic Beetle" and "The Birch Leaf-Mining Sawfly."

An active member of the American Association of Economic Entomologists, Dr. Friend has for several years served on the Advisory Committee, now the Publications Committee, of the JOURNAL

OF ECONOMIC ENTOMOLOGY. He is a member of the Entomological Society of America, the Society of Foresters and the Connecticut Academy.

P. P. CALVERT RETIREMENT

Professor P. P. Calvert and Professor J. P. Moore, Department of Zoology, University of Pennsylvania, retired at the end of the past academic year. Former students and associates held a dinner in their honor at the Hotel Normandie, Philadelphia, on the evening of May 31. More than 100 guests were present. Professor Calvert was presented with special equipment for his microscope and Professor Moore with a microscope. A large photographic portrait of each was presented to the university to be hung in the zoological laboratory.

ALUMNI COLLEGE LECTURER

For seven years, the Ohio State University has sponsored an alumni college program at the end of the academic year. Outstanding members of the regular faculty are chosen to bring once again to alumni the mental stimulation and pleasure they once knew in the classroom. The 1939 program included an address by Dr. Dwight M. DeLong, author of more than 100 technical papers on insects and their control.

Following is a synopsis of Dr. DeLong's address, "The Insect and Man in Conflict": "Man lives in a world filled with biological forms, all competing for an existence. One of man's greatest competitors is the insect, which outnumbers him three to one and is also better qualified than man, both by biological and physiological adaptations, to compete in the struggle for existence. The insect, through millions of years, has solved the problems of life and has become adapted to a natural chemical and physical environment. Man, by means of a superior intellect, is still attempting to solve the problems of life in the world by artificial adaptations of natural biological phenomena and conditions. The insect has adapted through selection. Man is still an experimental type in the world."

OF INTEREST TO NORTH CENTRAL STATES ENTOMOLOGISTS

Reports of the 1939 meetings of the North Central States Entomologists have been mimeographed. They may be ordered from A. G. Ruggles, University Farm, St. Paul, Minn. The price is 50 cents each.

Time of the next annual meeting was not definitely settled at the last meeting. Entomologists living in the colder states and those who work under the quarterly system in their colleges and universities have asked that the meetings in the future be held late in March. Professor Ruggles desires an expression of opinion from entomologists of the North Central states.

COMMEMORATING BURRILL

The hundredth anniversary of the birth of Thomas Jonathan Burrill was commemorated April 25, 1939, on the University of Illinois campus, Urbana, when graduate students and members of various departments which had their origin in Professor Burrill's leadership met with the seminar of the Department of Botany to hear an address by Dean J. C. Blair of the College of Agriculture.

Dr. Burrill was at one time professor of botany, horticulture and entomology. He was head of the Department of Botany at the time of his retirement in 1913. He is credited with having planted the avenue of elms which extends through the center of the campus and is generally recognized as the first scientist to demonstrate that a plant disease may be caused by bacteria.

PACIFIC SLOPE MEETING

Scheduled for June 27–29, 1939, is the annual meeting of the Pacific Slope Branch of the American Association of Economic Entomologists. Headquarters are announced as Lagunita Court, Stanford University, Calif.

R. W. Doane, Stanford University, is chairman of the local committee on arrangements. Officers of the Branch are Ralph H. Smith, Chairman, University of California at Los Angeles; B. F. Thompson, Vice Chairman, Oregon State College; John F. Lamiman, Secretary-Treasurer, University of California at Davis.

Sixty-two papers are listed on the program.

A joint session with the Pacific Coast Entomological Society will be held June 29 in the Academy of Sciences, Golden Gate Park, San Francisco.

TO AUTHORS

The following is from the Proceedings of the 1937 meeting of the Association of Economic Entomologists and is reprinted here for the information and guidance of authors preparing papers for publication in the JOURNAL OF ECONOMIC ENTOMOLOGY.

REPORT OF THE COMMITTEE ON COMMON NAMES OF INSECTS

No new list was submitted this year. In Volume 30, number 3, pages 527–560, a complete list of all names already approved by the Association, 999 in number, was printed. These are offered for sale as a separate.

So few new names were suggested during the current year that the Committee feels it inadvisable to submit a list for approval at this time.

Your Committee would like to recommend that the Association, having endorsed these names, make it obligative that if any common names are used on and after January 1, 1939, they be used in the JOURNAL OF ECONOMIC ENTOMOLOGY, and that the editorial staff refuse to accept for publication articles in which the author refuses to adopt the names approved by the Association. There should be no objection, however, to indicating in parenthesis a colloquial name in addition to the name approved by the Association.

J. A. HYSLOP, *Chairman*
R. B. FRIEND
H. B. HUNGERFORD
L. M. PEAIRS
H. S. SMITH
WILLIAM J. BAERG

(This report was received at the second session of the Executive Committee, and the recommendations were adopted at the final business session.)

Because publications differ widely in style, authors preparing papers for publication in the JOURNAL should read the instructions on the inside back cover of this issue.

HORTICULTURAL INSPECTION NOTES

IN regulations relating to seed Irish potatoes, as revised January 9, 1939, the South Carolina Crop Pest Commission designates 22 diseases and insects as pests and requires certificates as to all shipments within and into the state. Tolerances are provided for with reference to several of the pests.

MICHIGAN, Missouri and Nebraska have recently revised their alfalfa weevil quarantines, the two latter states having adopted the form approved by the Central Plant Board. Variances in these quarantines are shown in the areas designated as infested. Big Horn County, Mont., has been included in the Nebraska quarantine and omitted in the other two.

THE pink bollworm quarantine regulations were modified on March 30, 1939, by administrative instructions of the Chief of the Bureau of Entomology and Plant Quarantine (circulars B.E.P.Q. 492, 493 and 494), suspending or lifting treatment requirements as to shipments of designated articles from parts of the regulated areas.